MODERN BUILDINGS · THEIR PLANNING · CONSTRUCTION · & EQUIPMENT

EDITED · BY · G · A · T · MIDDLETON · A · R · I · B · A

MODERN BUILDINGS

THEIR PLANNING, CONSTRUCTION
AND EQUIPMENT

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THEIR PLANNING, CONSTRUCTION AND EQUIPMENT

BY

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PROFUSELY ILLUSTRATED

VOL. V

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PART II. ARMOURED CONCRETE AND MASONRY CONSTRUCTION
PART III. THE DUTIES OF CLERKS OF WORKS
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LONDON:
THE CAXTON PUBLISHING COMPANY
CLUN HOUSE, SURREY STREET, W.C.

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MODERN BUILDINGS

VOLUME V

PART I

ECCLESIASTICAL BUILDINGS

CHAPTER I

ESTABLISHMENT CHURCHES

At all periods of the world's history, and in all countries, the greatest architectural monuments have been those of a religious character; and not only has an effort always been made to render them architecturally the most beautiful, but also structurally the most sound, as they are built not for a single generation but to be of a lasting character. As a natural sequence of this, a certain type of plan which developed many ages ago has been adhered to with wonderful persistence, so that at the present time the buildings erected vary comparatively little in this respect, differing only in certain minor peculiarities to meet the needs of particular congregations and of certain varieties of ritual. This is particularly the case with Christian places of worship, with which we shall deal almost entirely, the plans of which are based upon those of the Roman basilicæ or justice halls—though certain modifications have been introduced from time to time, until at the present day it is possible to discuss the subject with but little reference to antiquity.

The simplest type of edifice now in use in the Church of England consists of a long narrow hall for the use of the congregation, this hall being almost invariably placed so as to lie east and west, and having an

·New Church·Four Oaks·

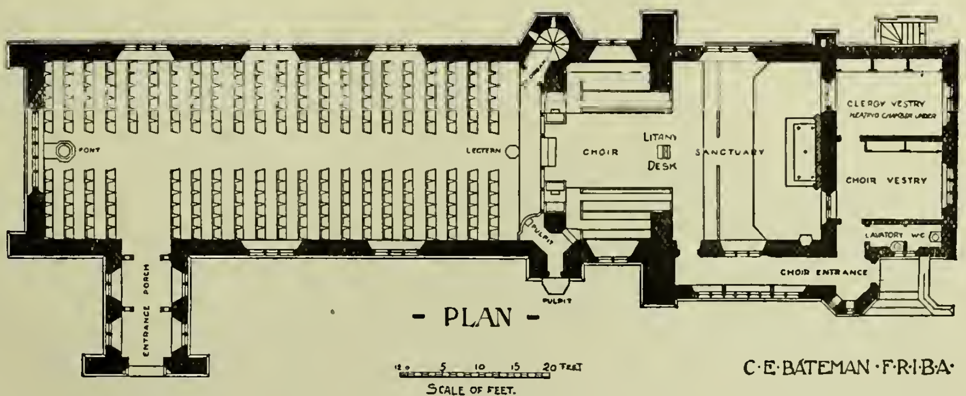


Fig. 1.

extension at the east end, known as the chancel, to serve for the use of the choir and the sanctuary, while, either at the west end or at the western extremity on either north or south, there is generally an entrance porch. Of such a type is the new church at Four Oaks, designed by Mr. C. E. Bateman, F.R.I.B.A. (Fig. 1), in which the porch is placed upon the south side. It has two doors, and so there ought to be little draught entering the building. The seating is arranged on either side of a central passage way. The font is placed at the western extremity, it being a generally accepted rule that its position should be as near the entrance to the church as possible, to symbolise the entry of a child into the Christian community.

In such a church as this there is no difficulty about either seeing or hearing, but the archway which separates the choir or chancel from the nave ought to

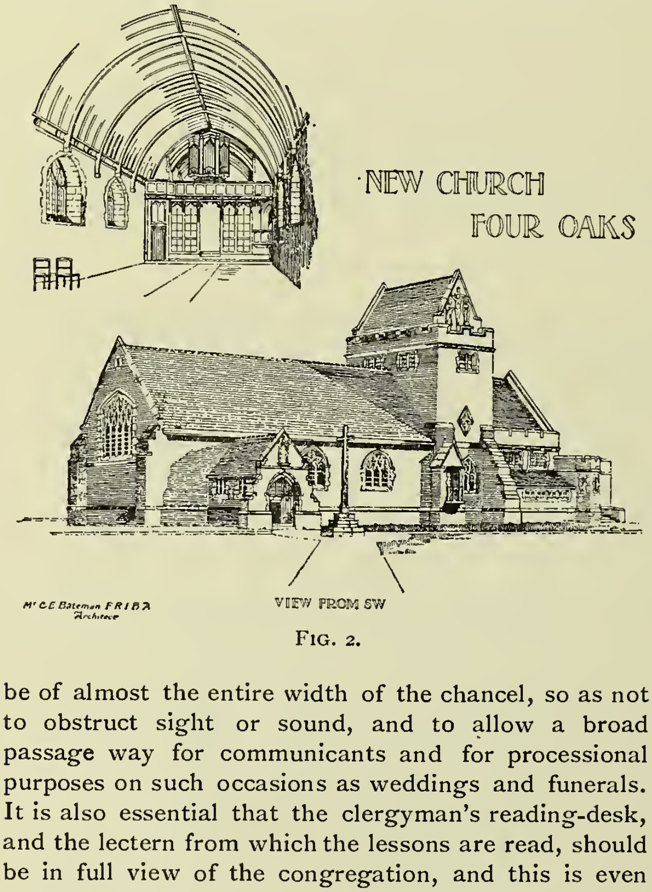


FIG. 2.

be of almost the entire width of the chancel, so as not to obstruct sight or sound, and to allow a broad passage way for communicants and for processional purposes on such occasions as weddings and funerals. It is also essential that the clergyman's reading-desk, and the lectern from which the lessons are read, should be in full view of the congregation, and this is even more necessary in the case of the pulpit. In the present instance the pulpit is placed on the south side, and is reached by a passage way through the wall which forms the abutment of the chancel arch, access being also obtained by the same means to an open-air pulpit—an exceedingly rare feature, particularly in country churches, though it is coming somewhat into use in the crowded parts of towns, as giving an opportunity for preaching to a class of congregation which can be reached by an open-air service, but will not enter a building. The organ is now admittedly a necessity, though its right placing is still a matter of considerable discussion. In a church of this character it is particularly difficult to so place it that it may be heard and yet not obstruct the view from any part, and the difficulty has been overcome by placing it over the screen which has been introduced between choir and nave, where, although it obstructs the view of the chancel roof, it does not interfere with either sight or sound of what occurs in choir or sanctuary, as will be seen in Fig. 2. The choir space is contrived under a central tower, which is utilised for the bells, the choir seats, as is usual, being ranged longitudinally. Beyond them is a sanctuary occupying the whole width of the nave, giving ample kneeling space for communicants, and wide steps for the clergy. As is usual in English churches, there is a square east end, for not only is this traditionally correct, but it is also economical to construct and convenient for the clergy, who are by no means so cramped as when the end is semicircular or semi-octagonal. A small recess on the south side is intended for the temporary deposit during the service of the vessels used in the communion.

In earlier times a single small vestry for the use of the officiating clergyman was all that was necessary, and in some of the older country churches even this is absent, and a small portion, perhaps under the tower, has to be screened off for the purpose. At the present day, however, even the smallest village church has its surpliced choir, and as a result two vestries become necessary, one for the choir and one for the clergy. These are often arranged on the north side, but in the present instance have been placed at the extreme east end, a position which they may very well occupy, especially if the ground rise in that direction, when they can be easily placed on the same level as the choir—which it may be noticed is generally raised about four steps above the level of the nave, while three more steps in all lead to the level of the communion table, which occupies the extreme east end of the church. The total number of seven steps, it may be mentioned, is scarcely ever departed from. In the case where the ground falls towards the east it is by no means uncommon for the vestries to be placed underneath the chancel.

When a church is required to seat a larger congregation than can be accommodated by means of the simple hall plan, it is usual to add aisles either at one or both sides of the nave, as shown in the Hill Church at Sutton Coldfield (Fig. 3), also designed by Mr. C. E. Bateman, the aisles being separated from the nave or hall by means of an arcade. The nave has a central passage in this as in almost all cases, while other passages are found to the north and south, serving the seats which are in the aisles, these being generally arranged between the side passages and the walls. A good deal of trouble is often taken to so place the pulpit and reading desk that the view of these may not be obstructed from more seats than is unavoidable, a

great deal depending upon the placing of the columns. In the present instance a western tower had to be provided, and the space within it has been utilised for seats, though this is somewhat unusual; and the porches are made to extend within the church, occupying positions whence the view would be obstructed if seats were placed there. It will further be noticed that all the seats face eastwards, as is always advisable, though in some cases it is not practicable. The choir and sanctuary are of the full width of the nave, so that the external effect of a transept (Fig. 4). It will be observed from this illustration that the aisles are lean-to roofed, without parapets, this being the general arrangement, although flat parapeted roofs are sometimes found, and span roofs more occasionally. It may be noted in passing that the nave passage must always be at least 5 feet wide; and although the aisle passages may be somewhat narrower, they should always permit of two persons passing with comfort.

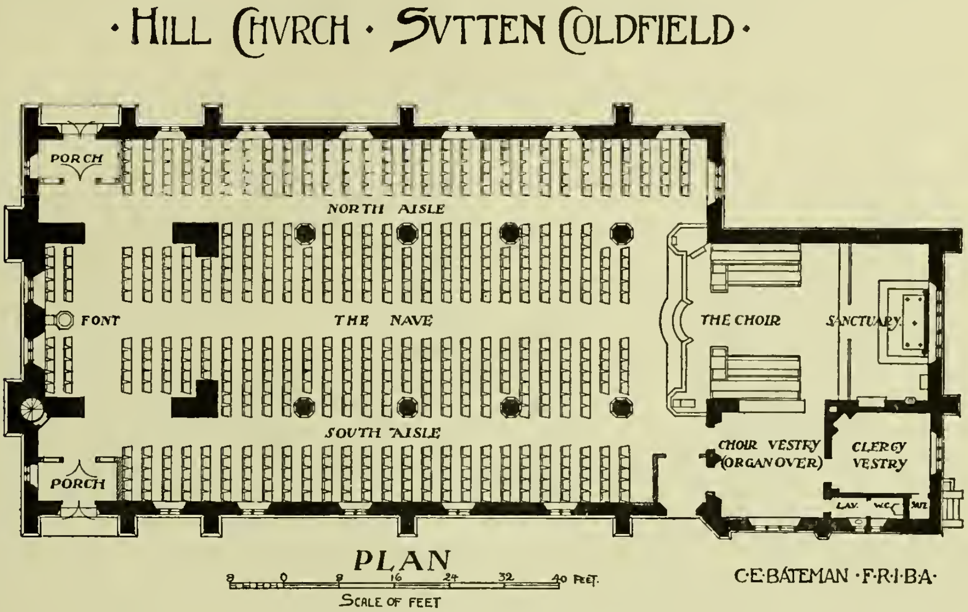


Fig. 3.

In the church of St. Andrew, Catford (Fig. 5), designed by Mr. P. A. Robson, A.R.I.B.A., the nave is made of much greater width in proportion to the length of the church, while the aisles are narrowed till they become mere passage ways, as may perhaps be better seen by the photograph in Plate I. As a result there is a good space between the choir seats for communicants to line up; but the vestries, instead of forming an independent building, are obtained by an extension of the south aisle, the choir vestry having an organ chamber above it, and thus being utilised to give

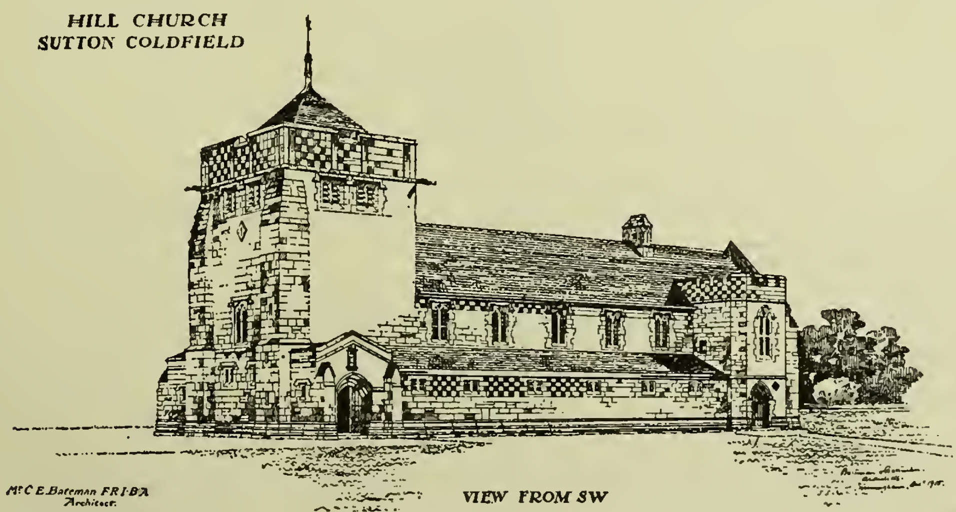


Fig. 4

of this there is scarcely a seat in the whole church from which a clear view cannot be obtained of the wide open chancel. The main entrances are at the east end of the two aisles. Sufficient accommodation for the whole congregation was not, however, obtainable in this nave, so that transepts have been thrown out at its east end, served by the aisle passage ways and seated to face eastwards. A good view can still be

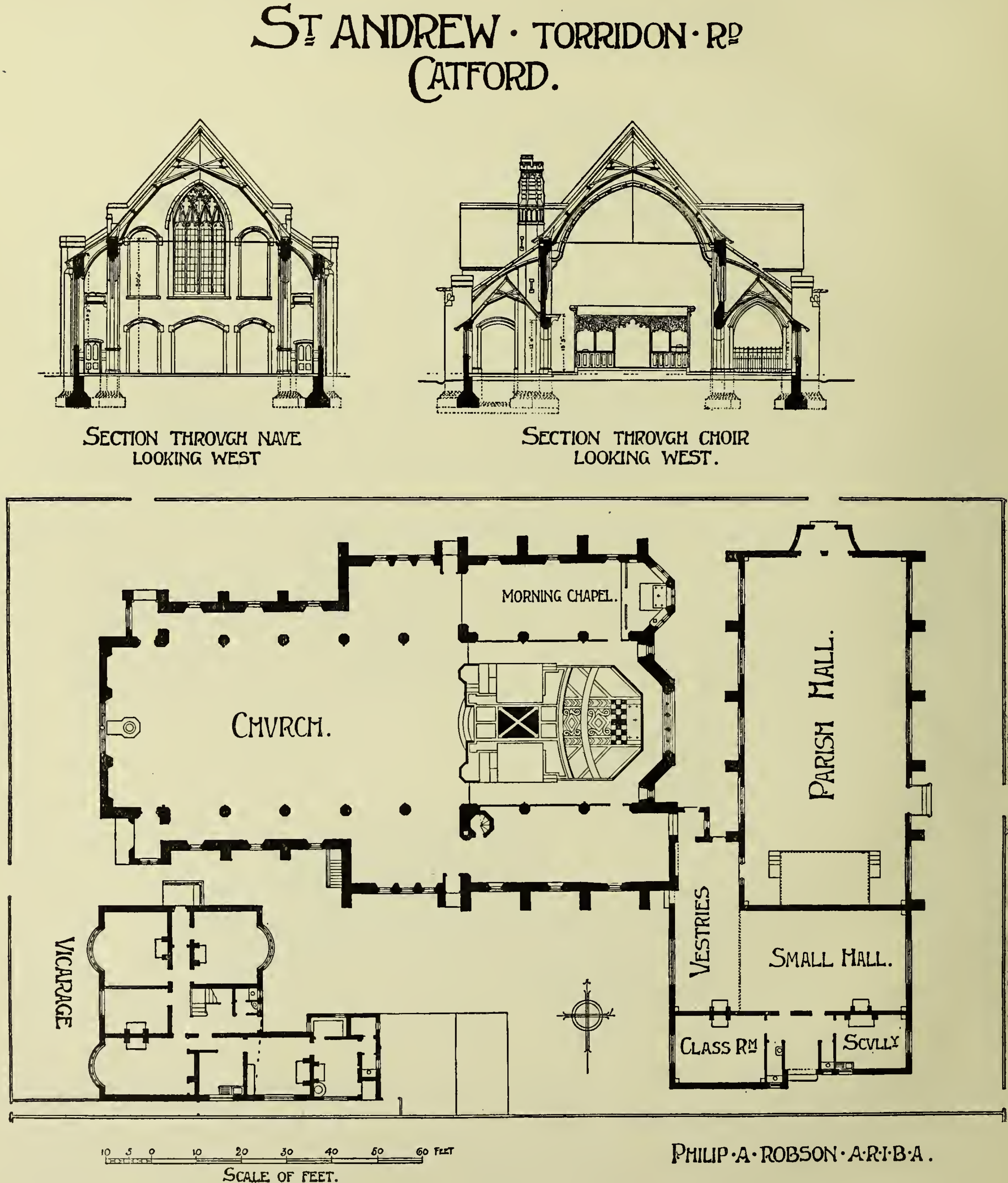
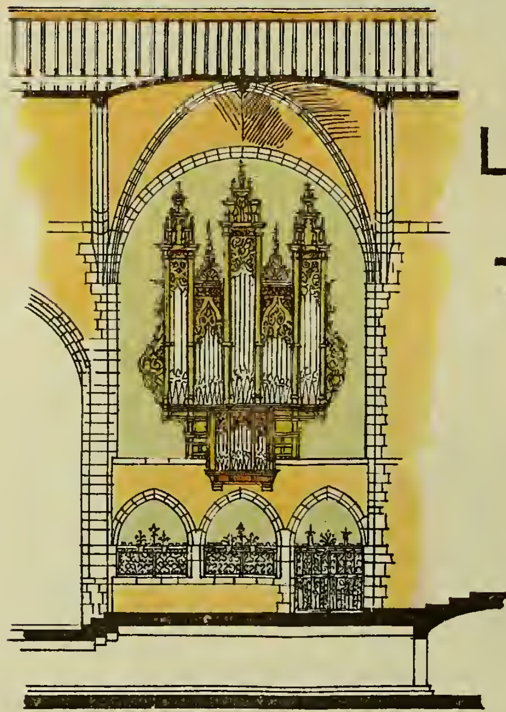


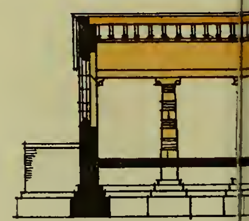
FIG. 5.

St. MARTINS CHURCH·EPSO

NICHOLSON & CORLETTE,
ARCHITECTS.

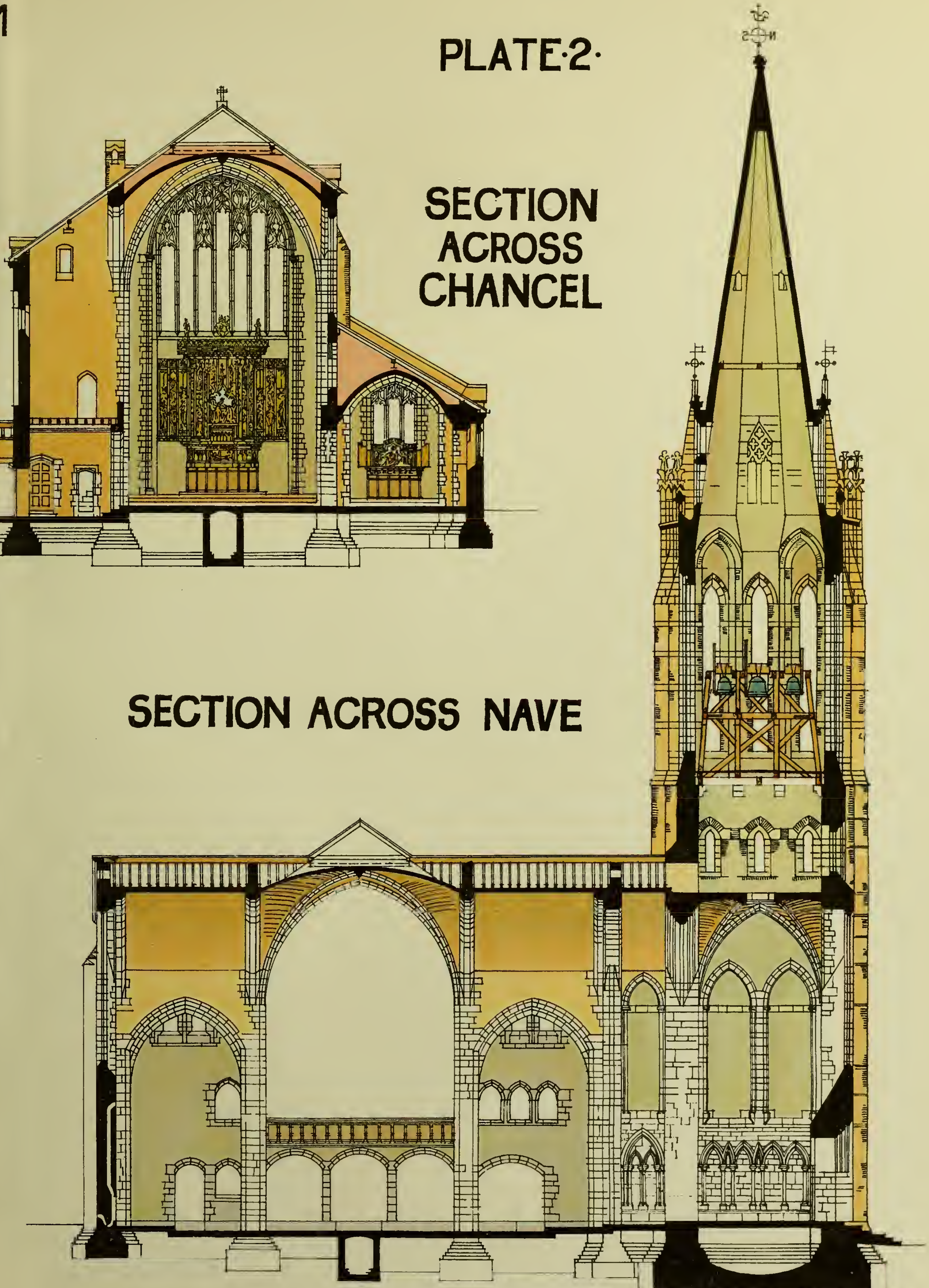


LONGITUDINAL SECTION THRo CHOIR



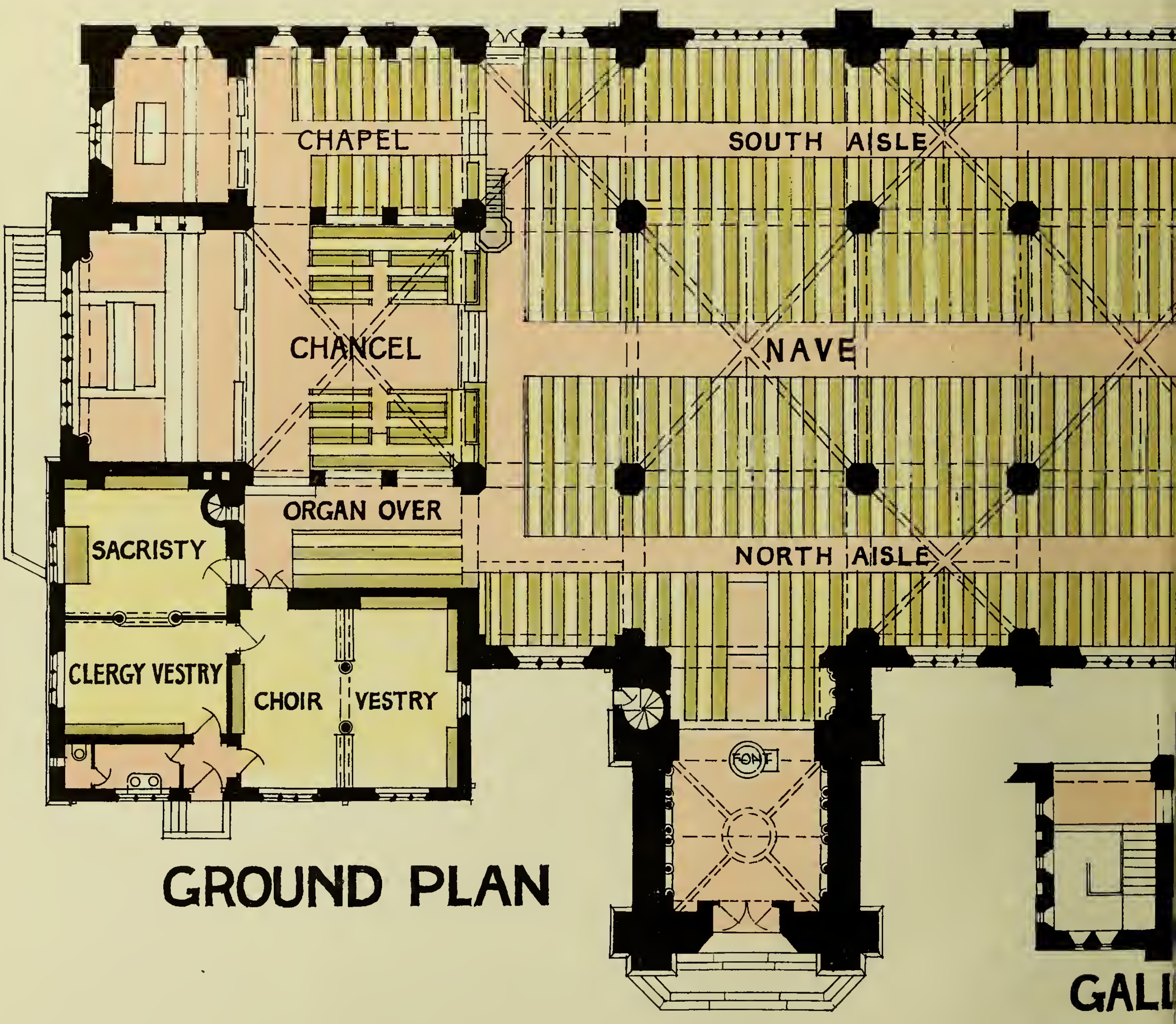
WEST ELEVATION


PLATE·2·



SECTION ACROSS CHANCEL

SECTION ACROSS NAVE

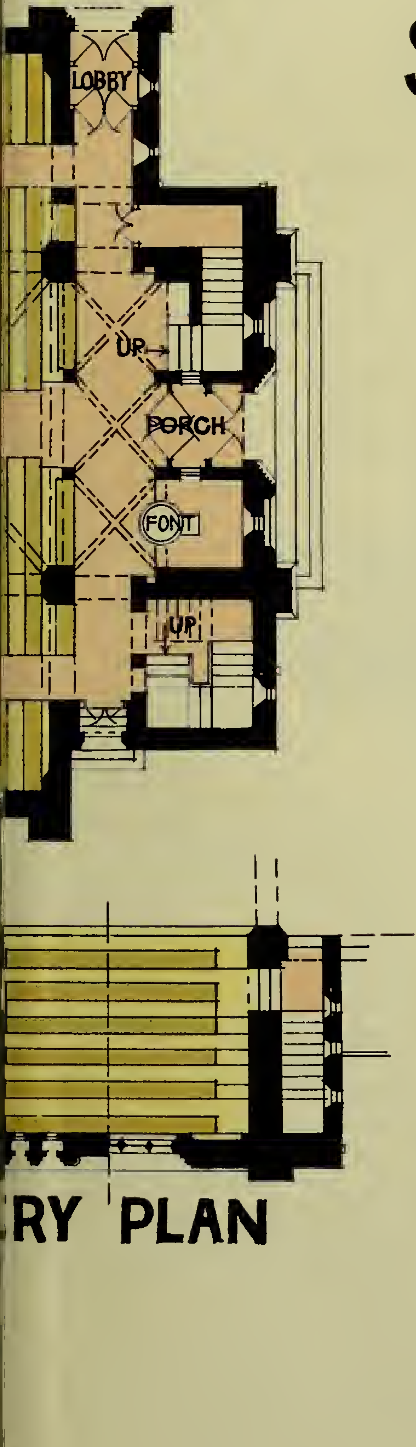

CHAPEL
SOUTH AISLE
CHANCEL
NAVE
ORGAN OVER
SACRISTY
NORTH AISLE
CLERGY VESTRY
CHOIR
VESTRY
FONT
GALL

GROUND PLAN

PLATE 2ª

ST MARTINS CHURCH · EPSOM · SURREY ·

SCALE 10 5 0 10 20 30 40 50 FEET



RY PLAN

SECTION ACROSS NAVE

NICHOLSON & CORLETTE
ARCHITECTS
2 · NEW SQUARE · LINCOLNS INN · W · C ·

obtained of the reading-desk and pulpit, though not of the communion table. The chancels are of nave width, with very little to mark the separation save an archway which springs from corbels. Use is made of this great width to provide return ways for communicants on either side behind the choir seats, this being almost essential in order to avoid passing where there is a large congregation and many attendants at the communion. The extension of the north transept is used as a small subsidiary church or chapel, known as a Morning Chapel, and intended for use at early communions and week-day services when only a small congregation is anticipated, while the additional seats are useful on occasions when the general body of the church is full. The organist sits in the southern extension, but the organ would be bracketed or corbelled out in the flank south bay of the choir, and on its east wall, facing west, in the south transept.

parishes at any rate. A smaller hall for committee and guild meetings, penny banks, etc., is also of great value, and is shown in this example as being separated from the vestry only by a sliding partition.

The group of buildings is completed by the vicarage, which differs but little from an ordinary detached house, save that a quiet study has to be provided for the clergyman, so placed that he can receive parishioners in it without their necessarily entering the body of the house.

The new church of St. Martin at Epsom (Plate II.) illustrates a parish church on a larger and more fully developed scale. There is the same general arrangement of nave and aisles. A central entrance is contrived at the west end, so as to secure a clear passage way for processional purposes, there being subsidiary entrances at the north and south extremities of a species of narthex or transverse hall at the west end—a screened-off portion enabling members of the congregation to obtain access to all parts from either entrance without passing within the body of the church.

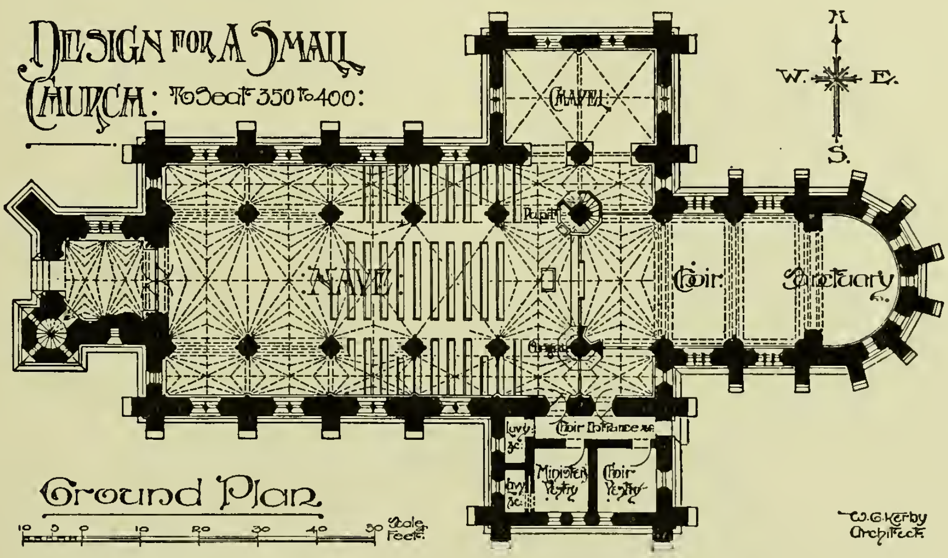


Fig. 6.

A village hall having been built simultaneously with the church, the vestries have been provided between the two buildings, so as to serve both, and a communicating passage has been arranged so that the clergy can reach the Morning Chapel behind the principal communion table, which is much preferred by many clergy to passing across the body of the church.

In many town parishes it is found that there are two different classes of congregations, one of which will attend the church proper, while the other, generally of a class which does not feel it can dress very well, will take no part in the full church service but will willingly enter a parish hall where a service of less formal character is conducted. Thus has arisen the need for such a building, which, as seen here (Fig. 5), is served from side and back roads, and has a platform at one end, accessible from the vestries but containing no communion table. This hall is used also for many other parish purposes, such as lectures and bazaars, and is, in fact, kept in constant use, in most London

This building has the somewhat unusual modern feature of a western gallery, under which the narthex occurs. The font is temporarily placed here, but the tower on the north side is intended to form the permanent baptistery as well as a secondary entrance to the church, and is planned with a view to its being built after the completion of the rest of the work. Again, the choir and sanctuary are of the full width of the nave, the return ways being arranged in the choir aisles, underneath the organ on the north and down the central passage way of the morning chapel on the south. The vestries are all placed on the north side and are of considerable size, there being a large choir vestry with stands and cupboards for vestments, besides a clergy vestry and a sacristy. This church has been planned for vaulting, all the others mentioned having been roofed with timber, and a beautiful

external effect has been obtained by carrying alternate bays of the aisles up to the level of the nave, barrel vaulting these higher portions while the low parts are cross vaulted. On comparing it with the other examples it will be seen that this secures very much better lighting of the interior, the high level aisle windows shedding a flood of cross light, such as is not to be obtained with clerestory lighting, unless the nave be carried up to a height which is not consistent with the organ round one of the nave piers in a position from which it can be well heard. The external appearance of transepts is secured, but actually they form no part of the congregational space, that on the north being occupied by the morning chapel and so screened off from the main building as hardly to be available for a nave service, and that on the south being devoted to vestries. An elaborate system of vaulting is shown, with the resulting stout buttresses, the church being

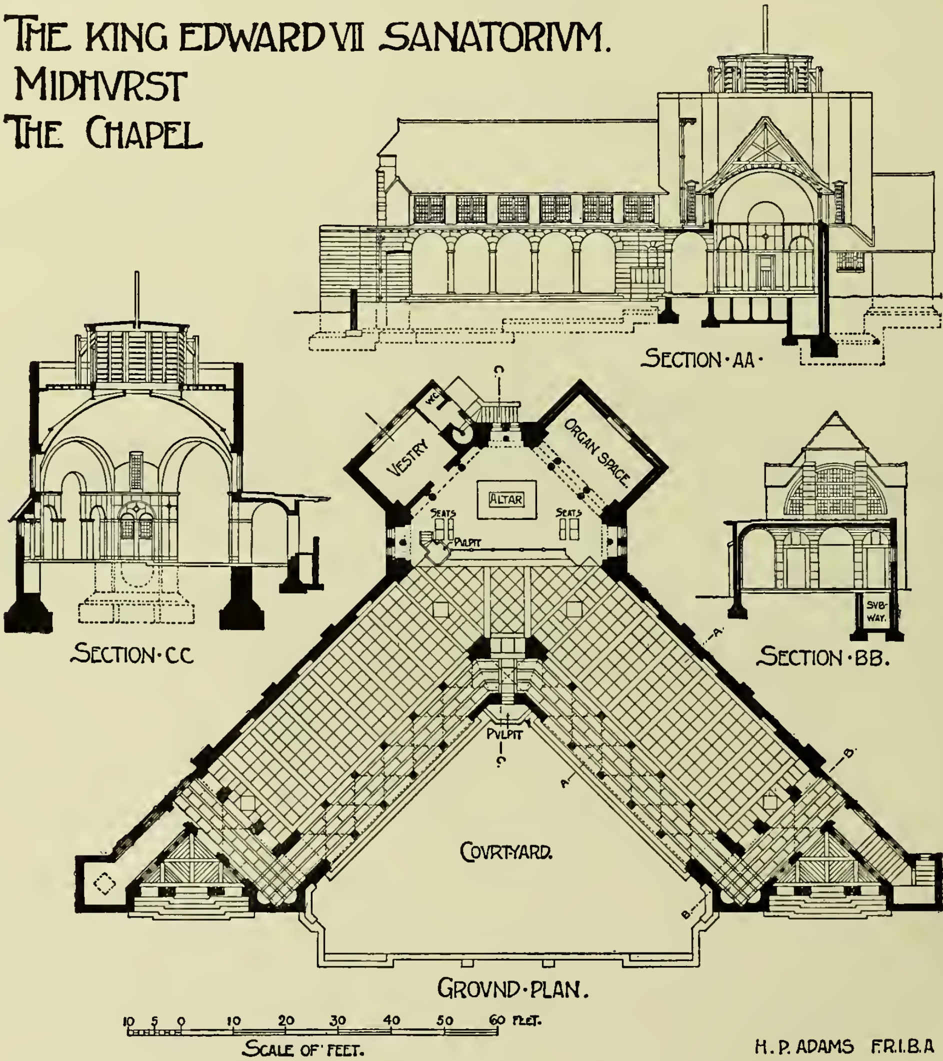


Fig. 7.

economy of construction. The ample height also gives the opportunity for placing the organ at a high level, and in such a position as to be heard all over the church.

Fig. 6 represents a church designed by Mr. W. G. Kerby, upon lines such as were frequently adopted in the Middle Ages, the tower being placed in the middle of the west front and the main entrance being obtained under it, so that there is a clear passage way from west to east. The choir has been brought forward into what, according to the general plan, might more properly be considered to be the nave, accommodating designed for architectural display rather than for economy, and probably for a somewhat high ritual.

Exceptions other than mere variations from the generally accepted type are rarely found, but an entirely unusual church has just been erected as the chapel to the King Edward VII. Sanatorium at Midhurst, from the designs of Mr. H. Percy Adams, F.R.I.B.A. (Fig. 7). This being an institution for the treatment of consumptive patients on the open-air system, it was necessary to plan the church on entirely new lines, and the device has been adopted of dividing the nave into two arms which open out from the

chancel like the two arms of the letter V, having an open colonnade or cloister along the inner side of the arms to serve as aisle passage ways from which the seats are reached, and perfectly open to the air. A considerable amount of trouble had to be taken with the plan, in order that the whole of the chancel might be visible throughout both the arms and to give architectural effect. An organ space has been contrived centrally opposite one arm and the vestry door correspondingly opposite the other, the chancel occupying half of an irregular octagon at the junction of the arms. Between these arms is a courtyard, with a second pulpit at their junction for the purpose of holding open-air services whenever the weather permits, so that the closed-in church will only be utilised occasionally or for communion purposes ; while if a shower should occur in the midst of an open-air service the congregation can pass into their seats immediately by means of the cloister. There is a narthex at the end of each arm to provide approach independently of the courtyard, up a flight of steps, and a subway is contrived beneath the cloister for the necessary pipes for heating and lighting purposes.

Another somewhat exceptional building is a school chapel. Like a hospital chapel, this is a comparatively private edifice, and so need not strictly conform with the Church of England rubric—in neither case, for instance, is a font necessary, and in each it is desirable to provide special seating for the inmates and for visitors, and sometimes in hospitals for the separation of the men and the women, or for different classes of patients. The chapel shown in Fig. 8 is one which is attached to a small private school designed by Messrs. Seth-Smith & Munro. The boys are scattered over a considerable area of land, where they live in separate houses, and so approach the chapel by an external porch, though in many schools it is reached by a cloister. In this case the visitors are seated in the gallery, the stairs to which occur close to the porch, while a special pew for the headmaster's family is arranged at the east end, so as to be accessible from the corridor communicating with his house. There is no separate chancel, but a small space is screened off at the east end to serve as a sanctuary. The prayers are read from the private pew, and only a lectern and pulpit are provided. As the singing is entirely congregational there has been no necessity to provide for a choir at all, though in many schools this forms an important feature. Of passage ways there are two, neither of these being central, there being no necessity to think of either weddings or funerals, the only requirement being that of easy access to all the seats. The organ chamber is scarcely part of the chapel at all, being arranged as one of a suite of rooms at its north side, which are devoted to musical purposes.

It is by no means uncommon in school chapels to arrange the seats longitudinally so that the boys face one another instead of looking eastwards. This renders

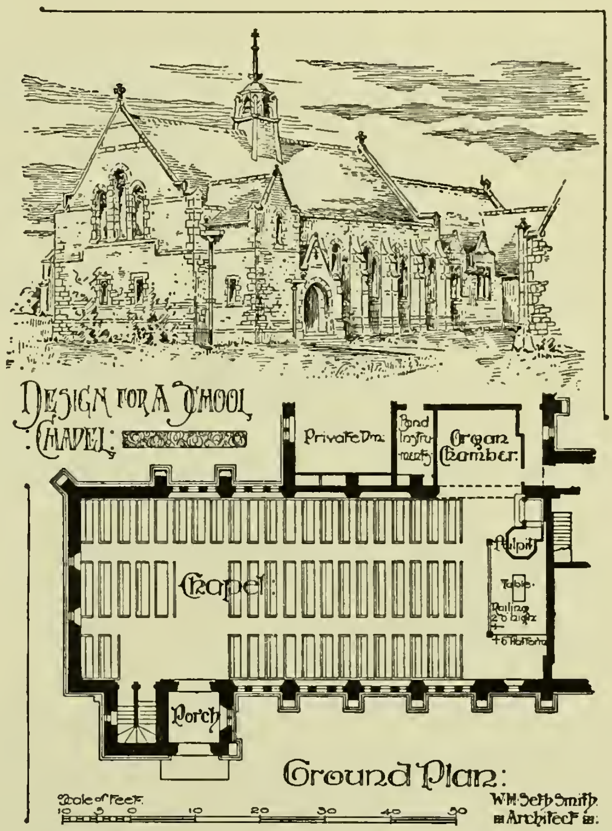


Fig. 8.

supervision easy, which has probably been the reason for its adoption, but it somewhat restricts the accommodation. Another plan, followed at the Felsted chapel, is that of placing the seats for the masters and visitors with their backs to the wall, while the boys' seats occupy the body of the chapel. The masters' seats are on a higher level, and consequently the rows of boys are under inspection from both sides, with the result that undetected misbehaviour is almost impossible.

CHAPTER II

ROMAN CATHOLIC CHURCHES

ROMAN Catholic churches differ but little from those of the Establishment, partly on historical grounds, and partly because the needs of the ritual are somewhat similar ; but it always has to be borne in mind that the English Establishment Church is an offshoot of the Roman Catholic, and that the great majority of the older churches in England were originally built for Catholic worship, and have been used since the Reformation without material alteration, save the destruction of side chapels and any intrusions within the general body of the edifice. These chapels, however, are essential to the Catholic ritual, and, as will be seen by referring to Fig. 9—the well-known church in Spanish Place designed by Mr. E. Goldie, F.R.I.B.A.—they have to be provided for. In this case it is done by means of double aisles, the outer aisle, both to the north and south, being given up to chapels, each of which occupies a bay or space between column and column. At present there are only four such chapels in this church, but it will be quite possible to increase the number by simply introducing them into a greater number of bays. These are independent of the large Lady Chapel, which, in the older places of worship, was usually found at the extreme east end of the church, but has here been placed in the south chancel aisle corresponding very closely in position and arrangement to the morning chapel of the Church of England, and, like the example at Catford, served by a passage

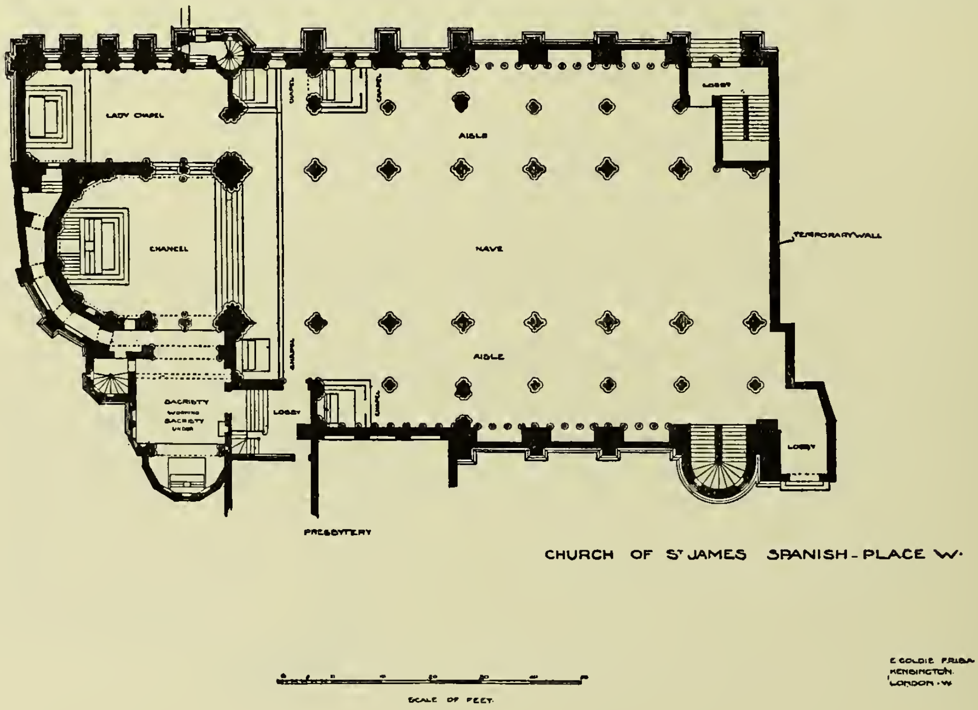


FIG. 9.

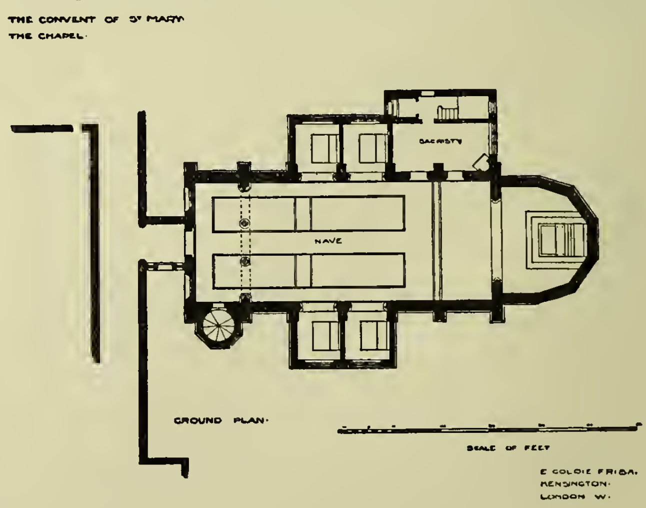


FIG. 10.

behind the east end of the chancel. Even more than in the Church of England is it necessary that the altar should be in view of the whole congregation. It has, if possible, to be placed a little forward of the eastern wall, to allow the steps to be introduced where shown; but there are few necessary obstructions, the reading desk, lectern, and litany stool being absent. At the same time, provision must be made for processions, so that a single-passage church is scarcely permissible, aisle as well as nave passages being necessary; and as a general rule movable seats or chairs are preferable to fixed pews, to enable the congregation to face in any

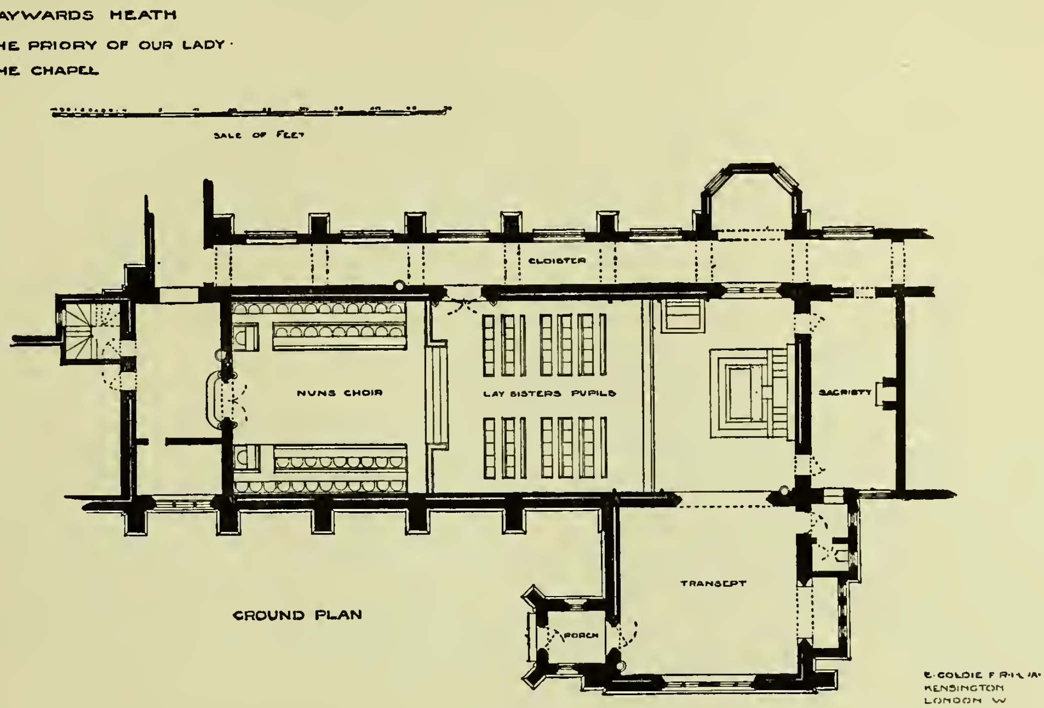


FIG. 11.

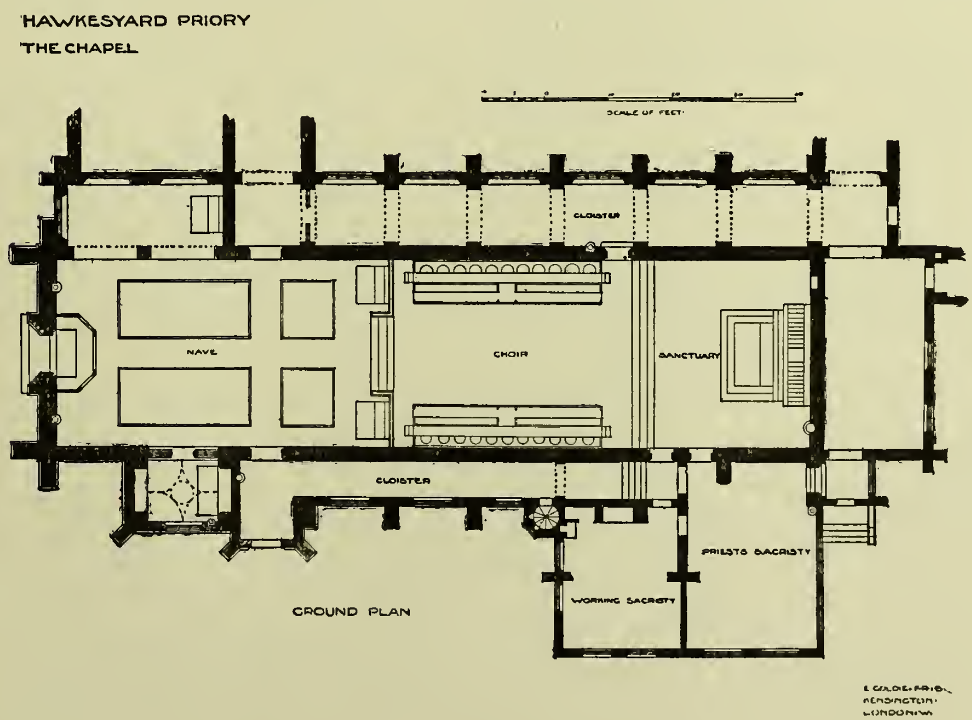


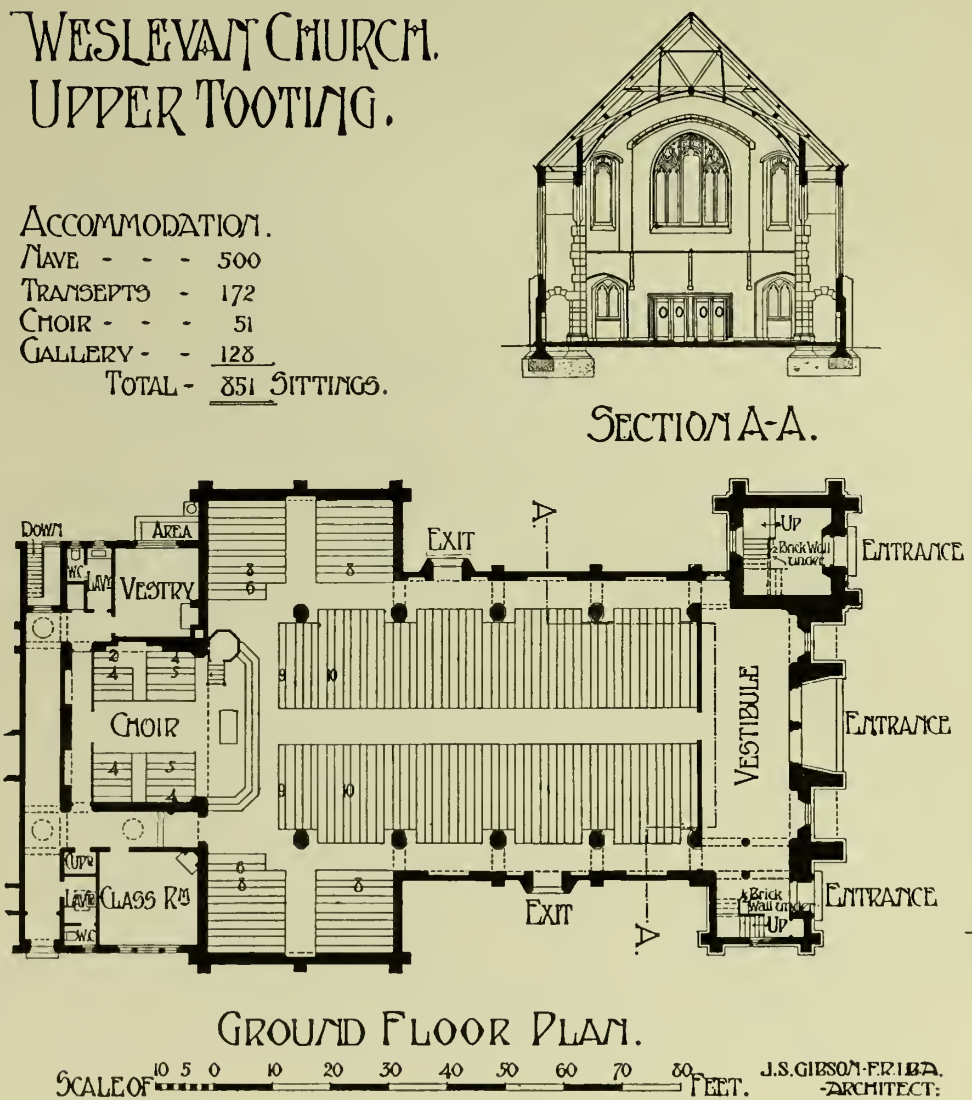
FIG. 12.

direction. As the vestments and other church furniture are frequently of considerable value, a treasury is occasionally added as an adjunct. At any rate, a good deal has to be made of the working sacristy, while, if possible, an altar is contrived in the greater sacristy.

Figs. 10, 11, and 12 represent smaller Roman Catholic churches on the hall principle, for use in connection with special buildings where subdivision of the congregation is necessitated. Fig. 10, for instance, represents the chapel in the Convent of St. Mary at Ascot, designed by Mr. E. Goldie, and is provided with nave and aisle passages, so that processions can be formed and easy access obtained to the four chapels which extend as transepts to the north and south. The seating is all arranged to face easterly, but is divided into sections for the inmates of the convent of different classes, and for the children belonging to the attached schools. A separate entrance is arranged to the sacristy. A view of the exterior will be found in the upper part of Plate III.

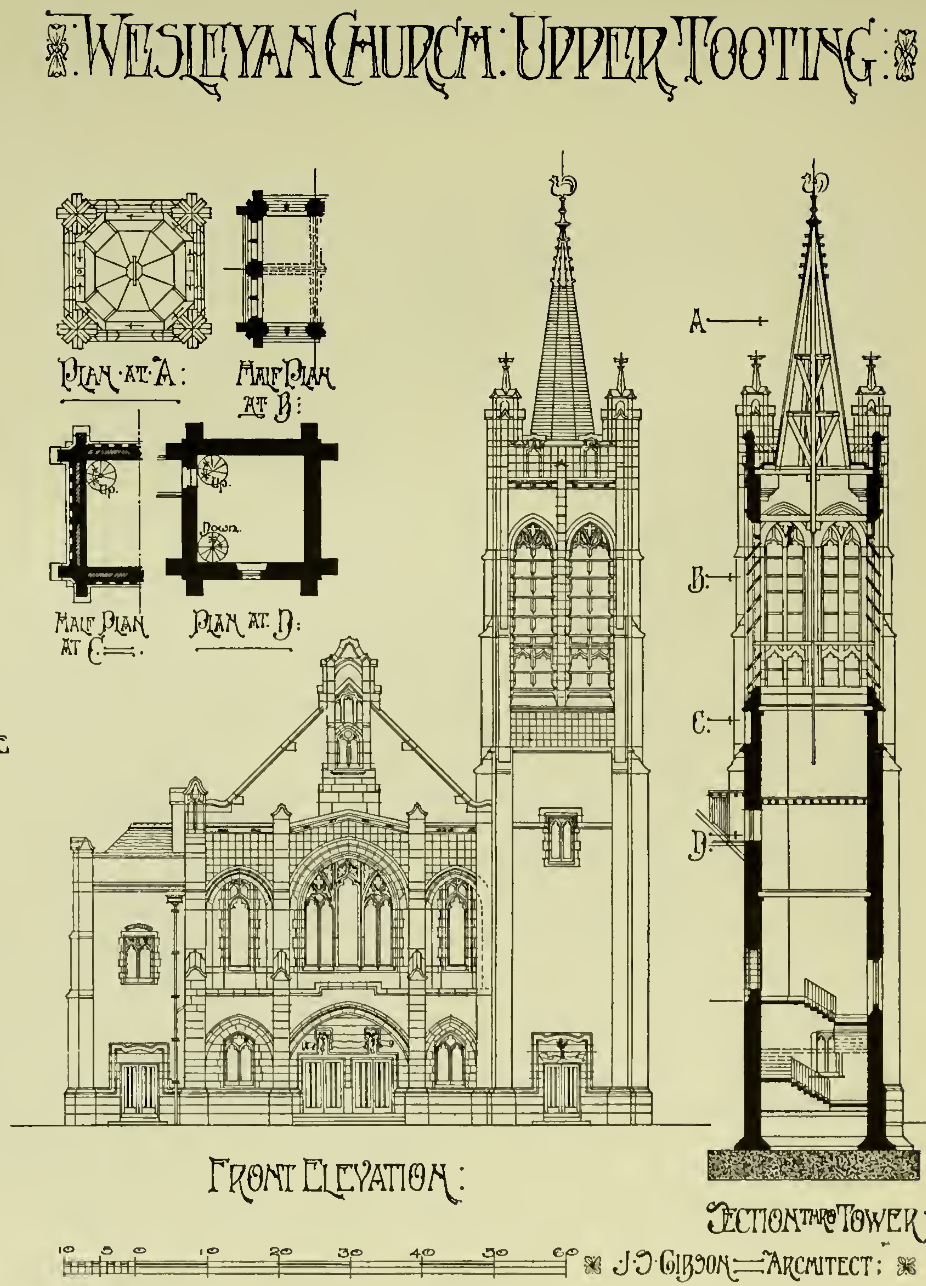
In the Priory of our Lady at Hayward's Heath, also designed by Mr. E. Goldie (Fig. 11), the division is carried somewhat farther, the central portion of the church being given up to lay sisters and pupils, who obtain access to it by a door from the cloister, while the western end forms the nuns' choir, with seats facing inwards, except for two for the use of the superiors, which are so arranged as to overlook those of the nuns. This, as observed in Chapter I., is a common arrangement in schools and colleges, and is often known as the collegiate system of planning.

Hawksyard Priory, again designed by Mr. E. Goldie, the chapel of which is illustrated in Fig. 12 and in the lower portion of Plate III., shows a similar arrangement save that the sacristies are placed on the south side, and there is a cloister also along that side to give access near the western end of the nave for processional purposes. In this case there is an external door for the use of the public, who are admitted as far as steps which rise to the choir, while a door at the northern side of the nave enables approach to this portion of the chapel to be obtained from the cloister also. In the Priory at Haywards Heath there had been no provision for chapels except one in the transept, but there is a large one on the north side and a small one on the south at Hawksyard. The separate entrance for priests from that used by the choir will be noticed, but otherwise the plan presents few additional or new features.



WESLEYAN CHURCH.
UPPER TOOTING.
ACCOMMODATION.
NAVE - - - 500
TRANSEPTS - 172
CHOIR - - - 51
GALLERY - - 128
TOTAL - 851 SITTINGS.
SECTION A-A.
DOWN
AREA
VESTRY
W.C.
LAV.
CHOIR
CLASS RM
CUPD
LAV.
W.C.
EXIT
A.
VESTIBULE
UP
2 Brick Wall under
ENTRANCE
ENTRANCE
Brick Wall under
UP
ENTRANCE
EXIT
A.
GROUND FLOOR PLAN.
SCALE OF 10 5 0 10 20 30 40 50 60 70 80 FEET.
J.S. GIBSON. F.R.I.B.A. ARCHITECT.

Fig. 13.



WESLEYAN CHURCH: UPPER TOOTING:
PLAN AT A:
HALF PLAN AT B:
HALF PLAN AT C.
PLAN AT D:
Up.
Down.
A.
B.
C.
D.
FRONT ELEVATION:
SECTION THRO TOWER:
10 5 0 10 20 30 40 50 60
J.S. GIBSON — ARCHITECT:

Fig. 14.

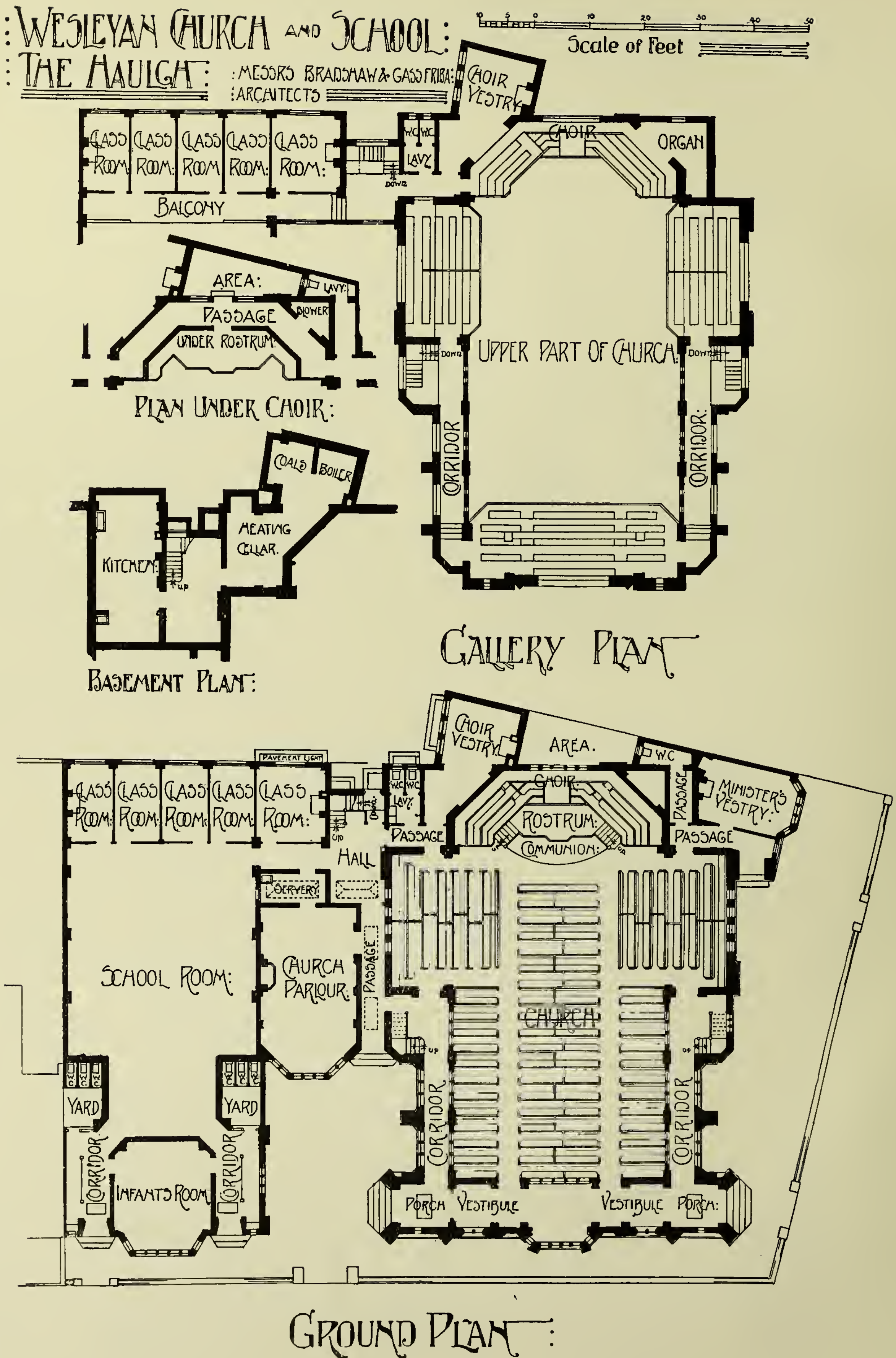

WESLEYAN CHURCH AND SCHOOL:
THE HAULGH:
MESSRS BRADSHAW & GASS FRIBA: ARCHITECTS
Scale of Feet
10 5 0 10 20 30 40 50
CHOIR VESTRY
CLASS ROOM
BALCONY
W.C. W.C. LAVY.
DOWN
CHOIR
ORGAN
UPPER PART OF CHURCH
DOWN
CORRIDOR
CORRIDOR
AREA:
LAVY.
PASSAGE
BLOWER
UNDER ROSTRUM
PLAN UNDER CHOIR:
COALS
BOILER
HEATING CELLAR.
KITCHEN:
UP
BASEMENT PLAN:
GALLERY PLAN
CHOIR VESTRY
AREA.
W.C
PAVEMENT LIGHT
CLASS ROOM
W.C. W.C. LAVY.
PASSAGE
CHOIR
ROSTRUM:
COMMUNION:
PASSAGE
PASSAGE
MINISTER'S VESTRY:
UP
HALL
SERVERY
SCHOOL ROOM:
CHURCH PARLOUR:
PASSAGE
CHURCH
UP
UP
W.C.
YARD
YARD
CORRIDOR
CORRIDOR
INFANTS ROOM
CORRIDOR
CORRIDOR
PORCH
VESTIBULE
VESTIBULE
PORCH:
GROUND PLAN:

Fig. 15.

The Chancel.

HAWKESYARD PRIORY, STAFFORDSHIRE.

[E. Goldie, F.R.I.B.A., Architect.

CONVENT, ASCOT.

[E. Goldie, F.R.I.B.A., Architect.

CHAPTER III

NONCONFORMIST AND EXCEPTIONAL PLACES OF WORSHIP

Speaking generally, Nonconformist churches and chapels differ but little in plan from those of the Establishment, this being particularly the case in the Wesleyan and Congregational bodies. In all instances, however, the ritual is rather one which gives prominence to the pulpit, so that there are cases in which the arrangement corresponds more nearly to that of a theatre than to that which is generally associated with a church, while in all instances galleries are more frequently used. It is difficult to understand why this should be, save on the score of economy, galleries being open to the serious objection that they are always difficult to supervise. A hundred years or so ago it was customary to put seating galleries into Establishment churches, but they have been given up almost without exception, as has the custom, still common on the Continent, of placing the organ and choir in a west end gallery.

The Wesleyan Church at Upper Tooting (Figs. 13 and 14), designed by Mr. J. S. Gibson, is an example of planning upon the generally accepted lines for English and Roman Catholic churches. It has a wide nave, and narrow aisles which serve as passages only, but the seats in the transepts are made to face inwards, the communion table being brought well to the front of the choir instead of being placed in a sanctuary at the east end. It is thus in a position from which it can be seen easily from the transepts, just as can the pulpit. As the church is somewhat close to a noisy road, the entrance has been very carefully screened by means of a narthex vestibule having a gallery over it, stairs to which are carried up on either side, in one case within the lower part of a tower, not yet completed, for the accommodation of bells. The construction of this is well explained in Fig. 14, and will be further detailed in a later part of this volume. The plan at A is particularly noticeable, as showing how the spire is arranged to sit upon the tower, the angles being corbelled across so as to form the octagon; while the plan at D, with its circular stairs in different corners, according to whether they go up or down, is somewhat unusual, the evident intention being to give access to the nave roof.

This matter of access is one which particularly influences the planning of churches, and requires a great deal of consideration, as all parts of the exterior, and particularly the windows, both externally and internally, should be accessible for cleaning and repairs without necessitating the erection of scaffolding; and it leads to the introduction of staircases in unexpected places, and of passages often contrived within the thickness of the walls.

The section AA on Fig. 13 is worthy of a good deal of attention, as the roof is of unusual construction, while sufficient buttressing is obtained to resist the thrusts by means of the transverse walls which are carried over the aisle passages, these being themselves slightly buttressed externally. One of the results of using the barrel form of plastered ceiling which is shown is that the acoustic properties of the church are unusually good.

The Wesleyan Church at the Haulgh (see Fig. 15), designed by Messrs. Bradshaw & Gass, is of a somewhat different type; for though it has transepts there is no nave arcade, the seats being reached by two aisle passages and by corridors which are external to the church itself, roofed at a sufficiently low level to allow clerestory lighting to the nave. At the extremity of these corridors there are staircases to side galleries which occupy the transepts, while they also serve a west end gallery over the entrance vestibule. A central rostrum takes the place of the pulpit, the choir being ranged round it, with the communion space in front. This is a reasonable plan to meet the requirements of the community, and the choir, rising as on a concert platform at the extreme end, should be able to produce a much greater volume of sound than in the ordinary Establishment church. Two choir vestries are provided, one at the low and another at the high level, but the minister's vestry is upon the other side of the church, communication between it and the choir-vestry being obtained beneath the rising seats of the choir, as shown on a special plan. In Fig. 15 a complete series of church buildings is shown, including a denominational schoolroom, with several classrooms and an infants' room, having the main entrances in front through corridor cloakrooms, which are distinct for boys and girls. There is also what is called a "church parlour" provided for small meetings, with a servery so placed that it might act as a refreshment-room when the schoolroom is utilised for such purposes as bazaars, there being a kitchen in the basement as well as proper arrangements for heating. It will be noticed that the group of buildings corresponds somewhat closely with that of the church at Catford already illustrated, except that the

schoolroom takes the place of the vestry hall, for many of the purposes of which it would probably be employed.

The Baptist Chapel at Farnworth, also designed by Messrs. Bradshaw & Gass (Fig. 16), is somewhat different, owing to the necessity of placing the large baptistery for the total immersion of adults within full view of the congregation, while further conveniences are added in the form of cloak-rooms attached to the accommodation as in the Wesleyan Church at the Haulgh, but differently arranged, the principal schoolroom being in this case on the first floor, while the kitchen service is contrived above the hall or passage which connects the church and school.

There must be separate ways for men and women both down to the tank and up again, and it is particularly necessary that there should be a separate heating apparatus, or at any rate a separate system of pipes, so

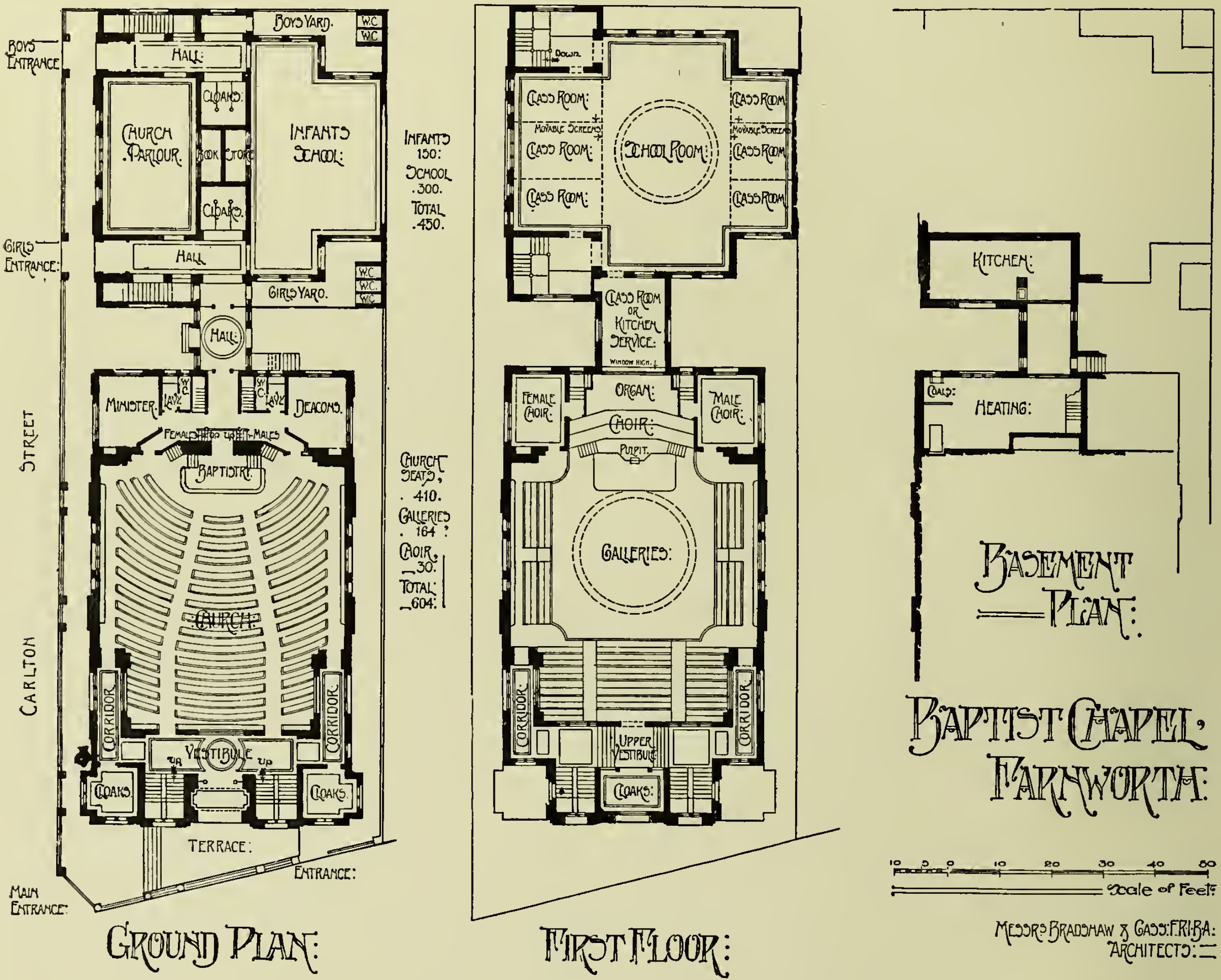


FIG. 16.

vestibule. The seats in the hall are arranged to radiate much as in a theatre, while the gallery is carried round three sides, so that from every seat there is a view of the baptistery and of the pulpit behind it. As in the last example, the choir is placed behind the pulpit, while the organ is behind that again. The choir reach their seats by means of stairs shown on the ground plan. There are separate vestries for men and women, which could be utilised also as dressing-rooms. At the back of the site, which extends along a side street, is a school and church parlour providing much the same that the water may be warmed independently of the room, it being essential for the sake of aged and infirm people that the water shall not be quite cold even in summer time.

It is not often that any other than Christian places of worship are erected in England, though Jewish synagogues are built occasionally, and it is contemplated at the present time to erect a Mohammedan Mosque in London, of which we are able to illustrate the plan and elevation in Figs. 17 and 18, as designed by Mr. W. I. Chambers. The principal features in such a

building is a large open hall or "Maysura," in which the worshippers may assemble and kneel where they please so long as they face towards one particular portion of it, the "Mihrab," so arranged as to be in the direction of Mecca. In the present instance this is obtained within the arcade, the greater part of the aisles being capable of being screened off and used for committee-rooms and other purposes, and thus not actually considered as part of the ritual Mosque. Another essential requirement is the tall tower or Minaret, from which the Muezzin may call the faithful to prayer. It is usual for such a building to be rectangular in plan as this is, the domical roof being commonly found wherever the Mohammedan religion prevails. In the present instance the design is based upon Indian work, but it is intended to use mosaic and other richly coloured material to a large extent for the purposes of decoration.

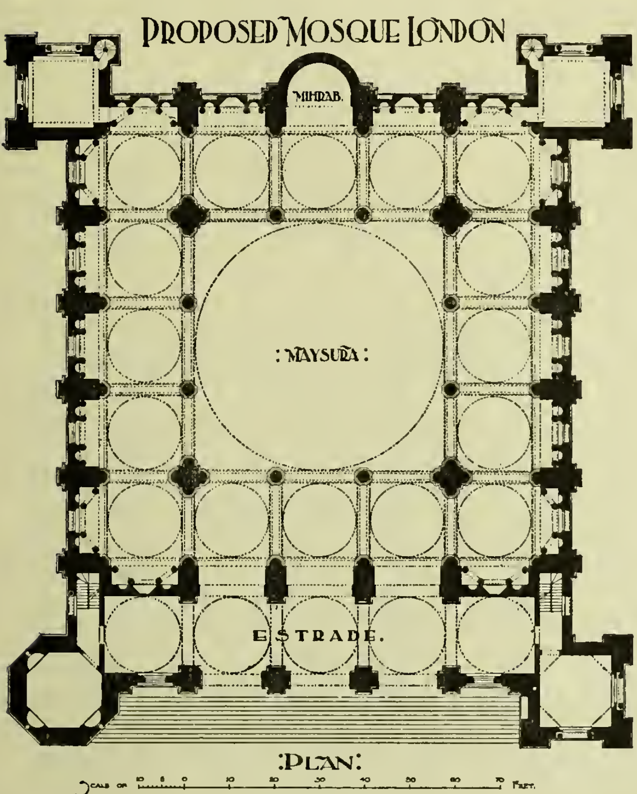


FIG. 17.

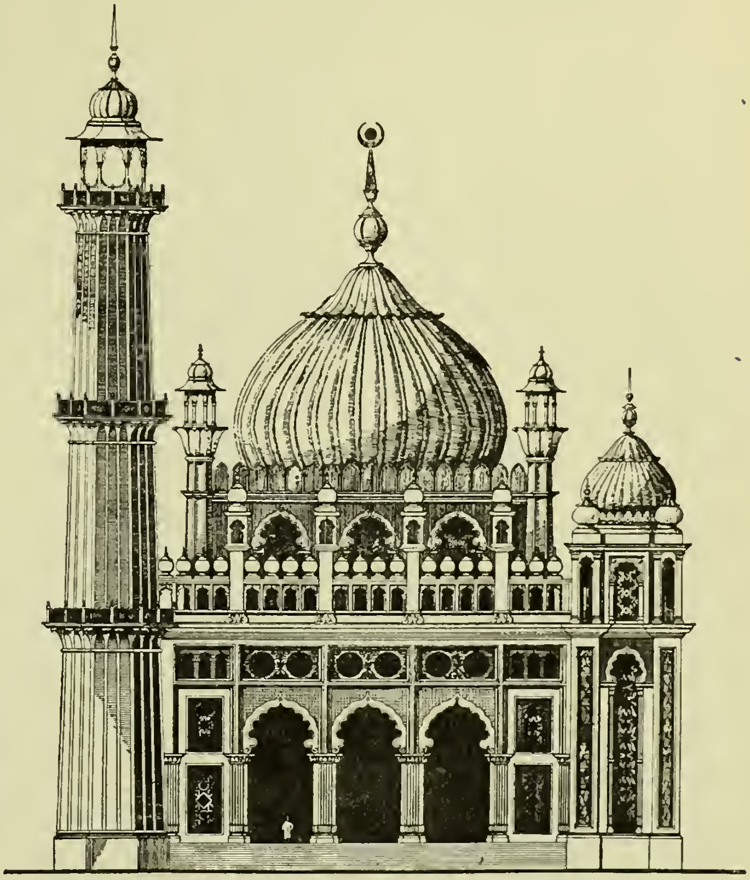


FIG. 18. *W. J. Chambers, Architect.*

CHAPTER IV

MORTUARY CHAPELS AND CREMATORIA

(*Contributed by* ALBERT *C.* FREEMAN, *M.S.A.*
Author of *Crematoria in Great Britain and Abroad*)

THE subject of provision for the dead is one of those questions which most men consider unworthy of more than a passing thought. Many do not care to think about or arrange for death, which must come to all of us; and even if they wish to do so there appears, at present, to be a feeling that nothing can be done but in the usual and old-fashioned way. It is clearly evident that the disposal of the dead, and the manner in which it is performed, is a question of vital and far-reaching importance. As our cemeteries become full we shall have to decide whether we are prepared to purchase large tracts of land, at exorbitant prices, and at some considerable distance from the centre of our towns, or adopt the more sanitary and hygienic method of disposing of the dead by cremation. There is no denying that as soon as a new burial-ground is opened the land and property in the immediate neighbourhood deteriorates and goes down in value. This would not be found to occur in the vicinity of a crematorium, as there would not be anything in regard to the process or the appearance of the building to effect any radical change. The advantages to be gained by the adoption of cremation are undoubted, as a great saving would be effected in the purchase of land, maintenance, and disposal of the cremated remains, and the bereaved would be relieved of the ill-effects and danger consequent on those gathered at the graveside in inclement weather, and the needless and extravagant expense of processions to distant cemeteries. Its adoption would also prevent a continuation of that crude and often ridiculous art of the so-called sculptor or funeral stonemason, who fills our cemeteries with a hideous vista of tombstones, void of beauty or proportion. It would result in place of this in the erection of noble memorials of great men in appropriate places, such as would benefit the living and beautify our cities.

Of the many classes of building which an architect is called upon to design, it would perhaps be difficult, if not impossible, to find one of which so few have had any practical experience as that of the design of Crematoria and Columbaria. The arrangement of a mortuary chapel is a subject on which all are more or less conversant. These small buildings, designed in an indifferent style of Gothic architecture, are familiar to most of us, while the design of Crematoria, of which so little is known, will, in the near feature, form most profitable work for the architectural profession, and open a new field of design which possesses great possibilities.

Italy was the first country to erect crematoria. Without exception the whole of the apartments are placed on one level, and in no case is the cremating chamber arranged beneath the chapel. At the Milan Crematorium provision is made of an entrance hall with a cremating chamber at the rear; but columbaria were subsequently added at either end of the building in the form of two large halls, with a crypt beneath each for the storage of urns of the poorer classes.

The crematorium at Turin (Fig. 19) is a masterly piece of design, which reflects great credit upon the architect. Here is an open colonnade, with niches for urns, encircling a small garden. It will be seen that a large hall or chapel is provided with a cremating chamber at the rear. At Florence and Bologna, provision is made of a hall with a cremating furnace standing in the centre,—in the former building the furnace is encased with marble in the form of a sarcophagus. Here the friends and relatives witness the introduction of the coffin into the furnace. Precisely the same arrangement is in vogue at Gothenburg, but the custom is one which is not allowed in this country. The crematorium at Paris comprises a large hall with three cremating furnaces, each standing within a small apartment at the rear.

At Rouen (Fig. 20) two distinct apartments are provided, a chapel and cremating chamber, similar in plan to the buildings of this country. In Germany the crematoria are arranged in two distinct forms, one with a cremating chamber at the rear of the chapel or hall, the other with the incinerating apartment beneath the chapel. In America, many interesting examples are to be found, varying both in plan and accommodation. The crematorium of the Odd Fellow Cemetery Company, at San Francisco, may be said to be the finest example in America. It has a chapel with seating accommodation for 140 people. Directly beneath the chapel is a reception or waiting-room, cremating chamber, and preparation-room. The coffin is carried into the waiting-room on the ground-floor level, and placed upon a lift which silently raises it to the chapel above,

where it remains until the conclusion of the funeral ceremony; when it is again lowered to the ground floor, to be subsequently placed upon a steel carriage and conveyed to the cremating chamber. Connected directly with the chapel is a gallery, running round

6 inches wide and 82 feet long, giving access to the cremating hall or chapel, which is 20 feet 6 inches wide and 56 feet long. Running parallel with this apartment is the incinerating chamber, which has accommodation for two furnaces. At the rear of the

Fig. 19.

three sides of the incinerating chamber, which is provided for those who wish to witness the work of introducing the casket and remains into the retort.

The crematoria at Troy (New York), Boston, Oregon, Buffalo, Oakland, and elsewhere are planned with the

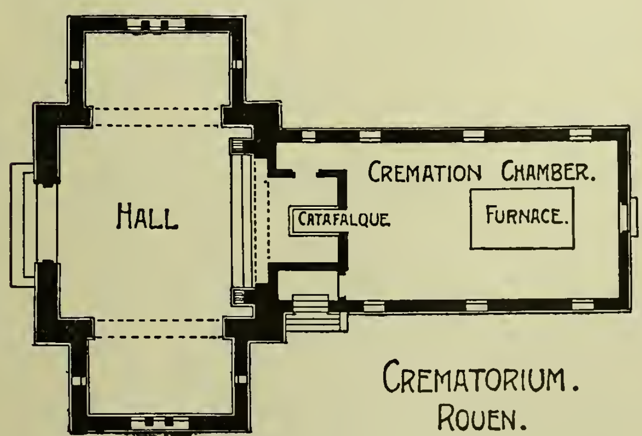


Fig. 20.

chapel and cremating chamber on the ground floor; while those at Milwaukee, Philadelphia, St. Louis, San Francisco, Fresh Ponds (New York), Chicago, and Davenport are constructed with the chapel either at the ground or first-floor level with the cremating chamber beneath. The crematorium at Montreal, Canada, has provision of a large conservatory, 40 feet

conservatory are three large vaults or columbaria for the storage of urns.

Passing to the crematoria in Great Britain, of which the example at Leicester is illustrated in Fig. 21, it will be found, with one exception, that provision is made of a chapel, cremating chamber, waiting-room or vestry, —and in some cases bier shed or small mortuaries, —the whole on the same level. At Glasgow the cremating chamber is arranged beneath the chapel, the coffin being lowered upon a lift, after the funeral service is read, to the chamber beneath. This form of plan has, however, its disadvantages, which will be explained when dealing with the design of the catafalque.

The Cremation Act

The first crematorium to be erected in this country was at Woking in 1879, but no cremation was performed until 1885, owing to the law forbidding the burning of human remains. In 1883 a cremation took place in Wales in defiance of the coroner's authority, followed by legal proceedings. These resulted, in 1884, in the decision of Mr. Justice Stephens declaring that cremation was a legal procedure, provided it was performed without nuisance to others. In 1884 the House of Commons refused to pass a bill for the regulation of cremation. The Government, however, in 1902, passed an Act for the regulation of the burning of human remains and to enable burial

authorities to establish crematoria. This Act, which came into force on the first day of April 1903, provides for the maintenance of crematoria and burial-grounds or anything incidental thereto, and stipulates that no human remains shall be burned in any crematorium until the plans of the site shall have been approved by the Local Government Board, and until the burial authority shall have given notice to the Home Secretary that the building is completed and properly equipped for the purpose. It provides that no crematorium shall be constructed within 200 yards of any dwelling, except with the consent in writing of the owner, lessee, and occupier of such houses, nor within 50 yards of any public highway, nor in the consecrated portion of any burial-ground of any burial authority.

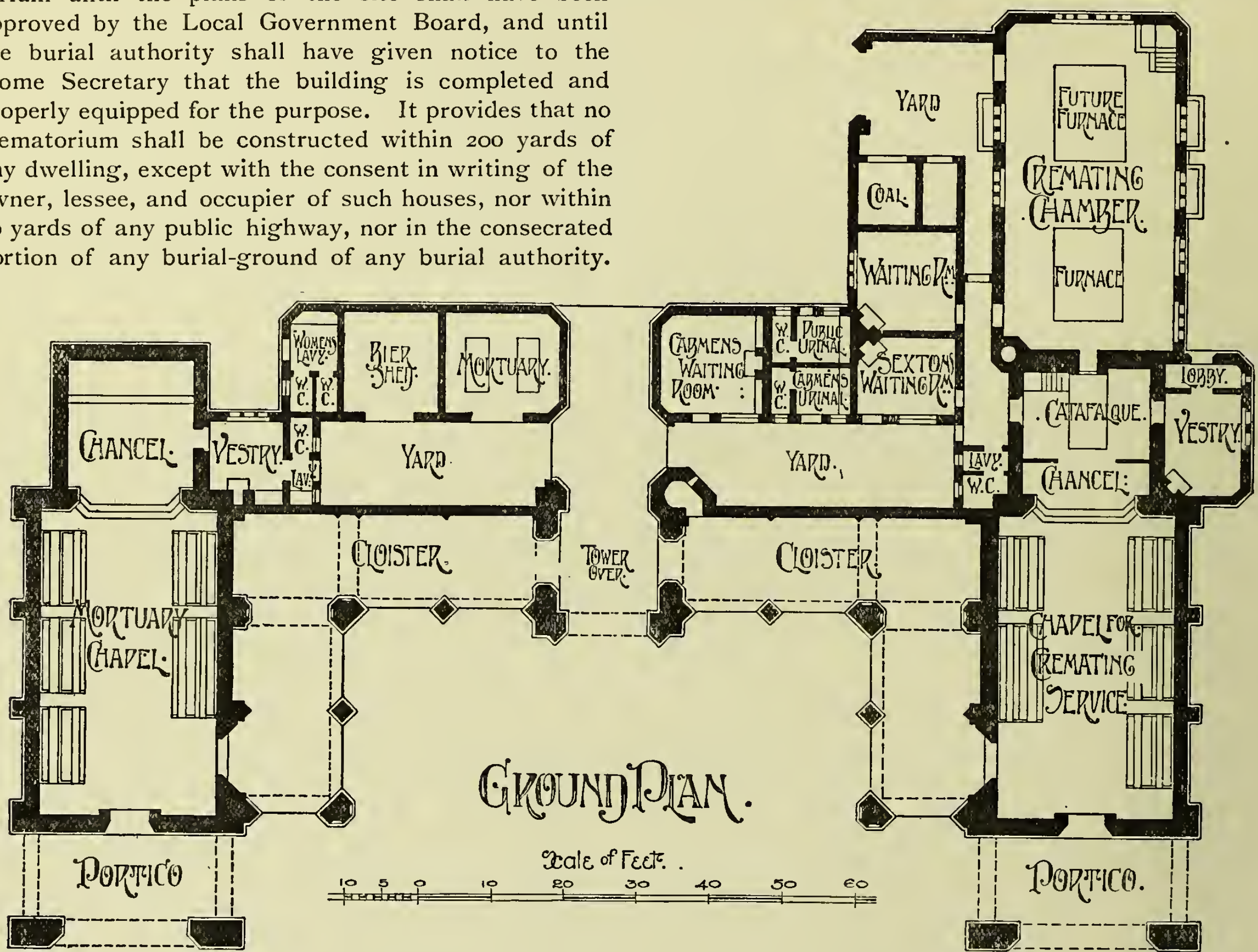


FIG. 21.—Crematorium and Mortuary Chapel at Leicester. [*Goddard & Co., F.R.I.B.A.'s, Architects.*

It might be mentioned that an exception was made in regard to the Ilford Crematorium, which is erected in a secluded portion of the Consecrated ground of the city of London Cemetery.

A great consideration in determining the plan of a crematorium depends upon whether any provision is to be made for the storage of urns, and as to the design and number of cremating furnaces to be installed.

In considering the particular position of the building on a site, it is well to remember that, though unconsecrated, they are in a great measure sacred to their particular calling, and therefore should be placed so that the head of the catafalque faces due east.

It must be borne in mind that the relative positions of the catafalque and the incinerating chamber should be such as will allow of the removal of the coffin and its contents from the chapel to the furnace with as little time and handling as possible.

The Chapel

In the design of the chapel the interior architectural treatment should be such as will not add any depression to a gathering necessarily sad. In determining the size, the first point to consider is that its superficial area shall be sufficient to allow of the provision of seating, clergy's desk, and the catafalque, in addition to any niches for urns. The chapels in the crematoria at Hull and Ilford are so small that little space is available for seating. The following are the dimensions of the principal crematoria in this country :—

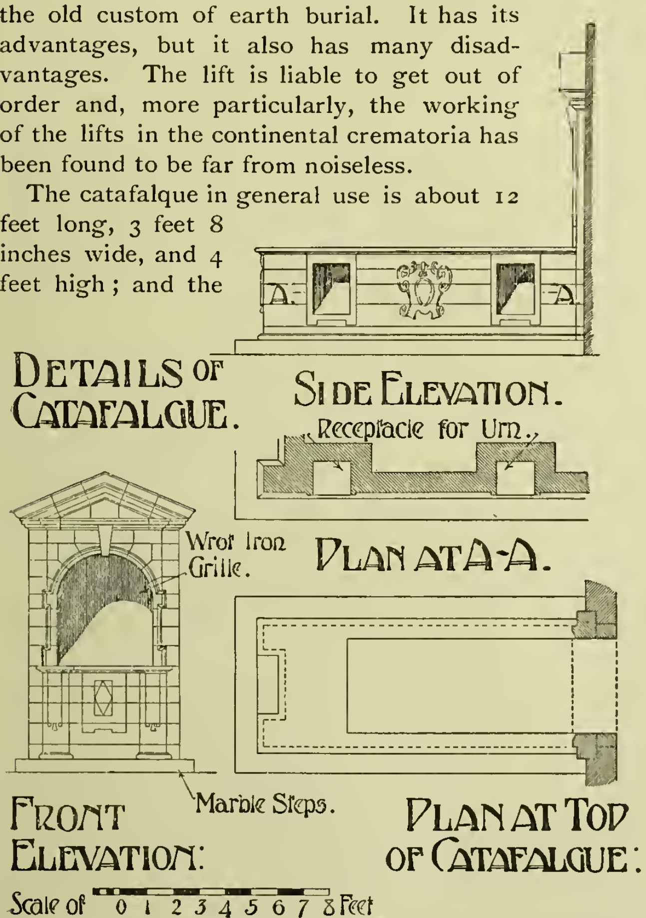
Woking, 48 feet long by 24 feet 6 inches wide ; Golders Green, 70 by 25 feet ; Manchester, 50 by 25 feet ; Leicester, 43 by 24 feet, with a chancel 17 by 17 feet 6 inches ; Birmingham, 50 by 25 feet ; Ilford, 25 by 24 feet, while the one at Hull is only 24 by 24 feet.

The chapel or hall ought to have a minimum floor space of 1200 superficial feet, which will allow for the provision of seating and the catafalque, and leave little or no wasted space.

The Catafalque

The catafalque, or table upon which the coffin is placed during the service (see Fig. 22) should be fixed with its head abutting the cremating chamber. When this is constructed beneath the chapel, then the catafalque should be so situated that when the coffin is lowered it will descend in front of or in close proximity to the furnace. It has been thought by some that, by placing the cremating chamber in the basement, the lowering of the coffin would be a less departure from the old custom of earth burial. It has its advantages, but it also has many disadvantages. The lift is liable to get out of order and, more particularly, the working of the lifts in the continental crematoria has been found to be far from noiseless.

The catafalque in general use is about 12 feet long, 3 feet 8 inches wide, and 4 feet high; and the



[*Albert C. Freeman, Architect.*

FIG. 22.—Design for Proposed Crematorium in connection with existing Chapel at Barbados.

top is fitted with an apparatus worked by means of an endless chain, which causes the coffin to pass from the catafalque to a carriage inside the cremating chamber. It is subsequently transported upon the carriage to the front of the furnace, into which it is quickly placed by the same means by which it is removed from the chapel.

Considering that the catafalque is the principal feature of the chapel, it should be of an artistic design, and the opening into the cremating chamber should also be in keeping with the purpose for which it is adapted. It is well if the opening at the head of the catafalque be fitted with a hammered wrought-iron or bronze grill in place of the iron doors and velvet curtains which are at present in general use.

Cremating Chamber

The first question to decide in the planning of this portion of the crematorium is the number of furnaces to be installed, and whether it is proposed to form it as an open chamber or with an intermediate or receiving room. It will be found quite sufficient if the portion of the chamber occupied by the carriage, while waiting to receive the coffin, is enclosed with black drapery to obstruct any light and view of the cremating chamber, and the increased cost of the receiving-room will be saved.

The following are the dimensions of the principal crematoria incinerating chambers in England: Golders Green, 62 feet long by 40 feet wide (four furnaces); Leicester, 43 by 24 feet (two furnaces); Birmingham 38 feet 6 inches by 25 feet, including intermediate chamber (two furnaces); Sheffield 36 by 36 feet (one furnace); Hull, 20 by 24 feet (one furnace); Ilford, 30 by 37 feet (two furnaces). When planned for a single furnace this chamber should have a minimum width of 20 and 25 feet in length, which will be sufficiently large for any furnace at present in use. In considering the design of this apartment it must be remembered that the front of the furnace should, in every case, stand 10 feet from the wall of the chapel, this being necessary for transporting the coffin from the catafalque. When one of Messrs. Simons' furnaces is installed a basement is required 6 feet 6 inches in height, to receive the lower portion of the furnace, and for the purpose of stoking and commencing the fire. With this furnace it is advisable to construct the floor over the lower chamber with a clear space around the incinerator, so that any expansion or contraction which takes place will in no way affect the structures.

Furnaces

There are at present four types of furnaces in operation in this country. Messrs. Simons', Toisoul, Fradet & Co.'s, the Carbon Oxide Company's, and the one at the Birmingham Crematorium, designed by Messrs. Wilcox & Raikes.

Messrs. Simons' furnace consists of three chambers, the two lower of which are surrounded by air passages. The lower chamber contains a coke fire, and the upper, or cremating one, is that in which the body is reduced to ashes. The fire is lit some time before the apparatus is to be used, and is supplied with air in the usual way. Before the introduction of the body, the air supply to the coke fire is greatly restricted; and after the body has been placed in the furnace a separate supply of heated air is introduced to the hot gases from the fire. The incinerating chamber is thus filled with intensely hot gas in a state of incandescence. The process occupies about one hour, and for each cremation an average of 12 cwts. of coke is consumed.

Messrs. Toisoul, Fradet & Co.'s is a gas operating furnace. The heating gas is introduced through Bunsen burners at the back end of the chamber containing the body, and the products of combustion pass out at the side near the front or entrance end of the chamber. The hot gases are then conveyed along flues and pipes underneath the furnace in such a manner as to highly heat the air supply to the bunsen burners, as well as a separate air supply that is arranged to enter the chamber at each side of the body at the latter stages of the process. The air supply to the bunsen burners is controllable, as also is that supplied separately to the sides of the cremating chamber.

It is estimated that about 6080 cubic feet of gas is consumed for each cremation, including that used in the pilot fire in the chimney, which at 2s. 2d. per 1000 feet (the price of gas in Leeds, where this furnace is in use) costs about 13s. 2d.

The Carbon Oxide Company's furnace, which is in operation at Golders Green Crematorium, may be said to be the most satisfactory of any used in this country. It is said to only consume about 7 cwts. of coke per cremation; and further, that there is not found so great an amount of expansion and contraction, during the heating and cooling, as is noticed in other furnaces.

Chimney Shaft

The chimney shaft should be placed in close proximity to the furnace, the internal measurements, at the base, being at least 2 feet square, and should be carried up to a height of 60 feet, though for the Carbon Oxide Company's furnace 50 feet is sufficient. The chimneys at Hull and Ilford are 70 feet, while the one at Birmingham is 80 feet high. It will be found from a study of the crematoria throughout the world that only in England is the chimney clothed with a tower; abroad, no pretence is made to hide its true purpose.

It is necessary to provide, at the base of the shaft, a pilot fire to warm the flue and assist the furnace when lighting up, consisting of a small fire grate, or, better still, a series of bunsen burners.

Columbaria

Having now given consideration to every phase of the crematorium, the next matter for our attention is the provision for the storage of urns. There are at present only two columbaria in this country, but they are not of any magnitude, but the Portland Crematorium at Oregon is planned with a chapel between 60 and 70 feet in length, having at each side four small apartments fitted with receptacles for urns, each columbarium having accommodation for the storage of about 250 urns, and at either side of the chapel latebræ are also provided, making a total of about 500 niches. The columbarium of the Odd Fellows Cemetery Company, at San Francisco, is designed in the form of a Grecian cusped cross, with the arms terminating in porches and connected by means of a pair of circular concentric walls. The rotunda formed by the inner walls is surmounted by a crowned dome. Provision is made for upwards of 1700 niches, varying in capacity from two to twenty urns on the ground floor; the first floor is a duplicate of the ground floor, with the exception of the quadrants being lighted from the top instead of the sides, and contains 1600 niches; and the second floor is similar to the galleries of the ground floor, with the exception of the wings and quadrants being omitted, and contains upwards of 700 niches, the capacities of which vary from one to ten urns, making a total of 4000. The columbarium at Golders Green Crematorium, London, is a tower-like building, 22 feet square, with four storeys and a crypt, having provision for the reception of 1700 urns. At the Liverpool Crematorium a small columbarium is provided in a crypt under the chapel. It is in the form of three corridors, on either side of which are arranged niches for the storage of urns, some of which are arranged to contain one and some as many as three urns.

In designing urn receptacles or columbaria, the latebræ or niches should be arranged to hold from one to five urns in a single compartment. The urns in use are known as the "box" or "vase" shape; the former measuring 16 by 8 inches, and being 8 inches high, while the latter are about 12 inches diameter and 18 inches high. The urn in general use in this country being of the "box" shape, provision should therefore be made, with few exceptions, for this design. In constructing the niches special attention should be given to the materials used, so as to occupy as little space as possible in the framing and divisions. The niches in the columbarium of Golders Green are constructed of Victoria stone, but the use of terra-cotta lathing, or thin partition blocks, plastered in Keens' cement, and painted or distempered, will allow of more artistic decoration. The fronts of the receptacles are closed with marble and glass tablets, or copper and wrought-iron grills, bearing the name and date of the deceased whose ashes are stored therein.

PART II

ARMOURED CONCRETE AND MASONRY CONSTRUCTION

CHAPTER I

ARMOURED OR REINFORCED CONCRETE: CONSIDERATIONS GOVERNING ITS ADOPTION

(*Contributed by P. R. Strong*)

CONCRETE has long been used in such positions as in the foundations of walls or in the construction of heavy retaining walls, etc. Its use in such positions is made advisable by the ease with which the component materials may be obtained and put in place, and also on account of the monolithic nature of the resultant mass. The small strength of concrete in tension restricts its application, when used by itself, to positions where the stresses to be resisted are almost entirely compressional.

The strength of concrete in compression may be taken to be roughly ten times as great as that in tension. Thus if a beam of plain concrete be constructed, its strength will depend upon its resistance to tension, which is small, while its high compressive resistance will never be brought into play. By reinforcing with steel or wrought iron those parts which are placed in tension the full compressional resistance of the concrete as well as the full tensile resistance of the metal may be made use of (see Fig. 23).

Probably the matter which most affects the advisability of using any particular form of construction is that of original cost as well as cost of upkeep. Although concrete cannot be disposed quite so advantageously as can steel, for instance, as regards its distance from the neutral axis, and although the weight of the resultant structure is greater, while at the same time much carpentry is necessary for moulds, yet the conjunction of concrete and steel is found, in the majority of cases to which it is applicable, to be cheaper than metal alone, even for bridging spans as large as 150 feet, and in some instances considerably greater. As the span of a structure increases, the weight of concrete militates against its economical use.

The second part of the question of cost, that of maintenance, is particularly small with this form of construction, which all experience gained hitherto goes to show is practically permanent and immune from deleterious effects of atmosphere. In fact, it may be said that the strength of concrete will improve for an

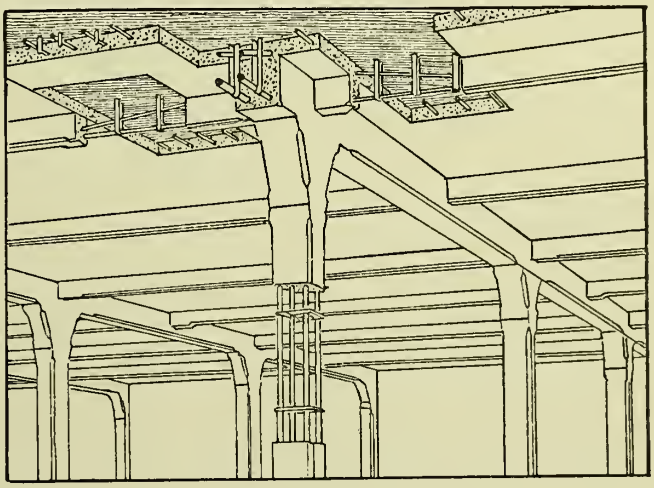


FIG. 23.

indefinite number of years after construction, while the steel is apparently perfectly protected from deterioration.

ADVANTAGES IN THE USE OF ARMOURED CONCRETE

1. *Small Cost, and consequently reduced Capital Expenditure.*—The difference of cost between this and other methods of construction must, of course, depend largely upon the locality and the readiness with which the various materials may be procured, as well as upon the form of the structure in which it is to be used. In cases in which the use of armoured concrete is suitable it will generally prove to be cheaper than either steel or masonry, while a saving of as much as 20 per cent. is sometimes obtained by its use.

2. *Permanency.*—As stated above, concrete is unaffected by weather, rain, frost, smoke, etc., while the embedded metal is thoroughly protected against corrosion (see p. 165, Vol. IV.). The saving in cost of maintenance as compared with that of simple steelwork is considerable, while the dangers attendant upon the disregard of the prevention of corrosion of steelwork are at the same time obviated. In this respect the contrast between the metal embedded in armoured concrete and that encased in a steel frame building such as was considered in Chapters XIV. to XVII. Part II. Volume IV., is particularly worthy of notice.

3. *Adaptability.*—The ease with which it can be applied to almost any form of construction renders this material particularly convenient; for instance, in an ordinary building it may be applied with economy to foundations, walls, roofs, pillars, floors, and girders.

4. *Resistance to Fire.*—The value of concrete as a fire resistant was discussed in Chapter II. Part III. Volume IV., where its value as a protection to steel was set forth. It is clear, then, that armoured concrete in which all metal is entirely embedded may be rendered eminently fire-resisting; but it must not be concluded, as is frequently stated, that all armoured concrete is satisfactory in this respect. As set forth already, the resistance of concrete depends largely upon the aggregate of which it is composed, while for prolonged protection the metal must be surrounded by concrete of moderate thickness; $1\frac{1}{2}$ inch is generally considered a suitable thickness beyond the surface of metal in beams, while this may be reduced to 1 inch in the case of slabs; but this thickness should never be decreased.

5. *Rapidity of Erection.*—Steel in the form used is readily obtainable, and there is little fear of delay in procuring it. As compared with brickwork, the wall thicknesses are much reduced and the walls are consequently constructed with greater despatch, while when compared with steelwork the girders and pillars would be in place long before girders and stanchions of steel could be constructed at the steel works. The rapidity with which a building can be constructed and made ready for use is a most important point, for the land on which the building is erected, as well as that part of the building already built, represents so much capital lying idle. This is a point which is apparently hardly realised in England. The possibility of constructing quickly and at the same time soundly is not one of the least important of the advantages of armoured concrete.

6. *The Use of Unskilled Labour.*—The actual mixing and putting in place of the concrete can be done by any labourer of ordinary intelligence; but at the same time a high standard of carpentry is necessary for the extensive moulds and centering that are required, while much ingenuity may be displayed in its design and arrangement. A reliable clerk of works is an absolute essential on works of this description.

7. *Economy of Metal.*—No metal is removed for the insertion of rivets, etc., and therefore the whole of the embedded metal may be usefully employed. The labour required upon the steel is extremely small.

8. *Freedom from Vibration.*—Vibration depends upon the ratio of live to dead load, and also upon inherent stiffness. In both these respects armoured concrete has an advantage over metal structures, and, as compared with the latter, vibration is very small indeed.

9. *Absence of Joints.*—The absence of joints gives increased strength and rigidity, while girders pass through those at right angles to them without break, thus rendering one another mutual support.

10. *Light Arches.*—As compared with masonry structures the weight of arches may be considerably decreased, for it is no longer necessary to restrict all stress to that of compression.

11. *Permanency in Sea Water.*—When used in the construction of maritime works it does not suffer from corrosion as does iron, nor does it suffer from the ravages of marine worms as does wood.

Disadvantages in the Use of Armoured Concrete

1. *Quality of Resultant Material cannot be seen before it is embedded in the Work.*—Unlike steel construction, in which the strength of all material may be tested, and in which the workmanship may be inspected at intervals, in the case of armoured concrete the quality of the work will not be evident until it is thoroughly embedded in the structure, unless indeed the various parts are moulded in advance and are afterwards set in position, as is sometimes done. The latter method has the further advantages of requiring fewer moulds, of saving the need for timbering, and consequently giving greater freedom from props between floors, while also the moulding may be done under cover, and the pieces may be set in position when thoroughly set.

2. *Bad Workmanship.*—Strength is much impaired by faulty workmanship, by insufficient mixing, by using wrong proportions, by allowing concrete to partially set before putting it in place, by frost during setting, by misplacing the reinforcements, by vibration of moulds during setting, and by the use of faulty materials. All these possibilities of wrong-doing go far to render scientific design useless, and unless they can be avoided the use of armoured concrete is not advisable. However, they may in a great measure be overcome by careful and continuous supervision, and this must be looked upon as an absolute necessity, particularly where an attempt at lightness of construction has been made.

3. *Calculations.*—Strictly scientific calculations in design are practically impracticable. The properties of concrete vary largely with the materials used, with the quantity of water employed in mixing, with the method of mixing, and with the after treatment. It is impossible to arrive at any very definite figures on which to base calculations, while at the same time the disposition of stresses in beams, etc., has by no means been accurately established. If care be used, however,

moderately uniform and satisfactory results may be obtained.

4. *Time taken in Setting.*—This results in much obstruction of space by the props necessary to support floors and beams, which must be left in position for several weeks while the concrete gathers strength.

5. *Interruptions in Concreting.*—It is necessary to discontinue concreting in order to stop work for the night, and at other times while further moulds are being fixed. This slightly affects the continuity of the concrete. In the case of beams the joint between old and new work should be arranged if possible to come immediately over the pillars, or at any rate at those points where the concrete is under compression and shearing stress is small.

6. *The Invisibility of Metal.*—The metal being completely embedded and hidden in the concrete, the strength of a beam already constructed cannot be ascertained by measurement and calculation.

7. *Monotonous Appearance* when used for external walls. The chief use of armoured concrete is not in this position ; but architectural effect may be produced with the aid of cement rendering and by carefully forming reverse details on the wooden moulds (see page 137, Vol. I.). A strong feeling very rightly exists against the imitation of stonework in this material. Buildings should not be designed to ape massiveness, and all ornamentation beyond the beauty of lines should be confessedly the decoration of a monolithic material.

Uses.—The uses to which armoured concrete may be advantageously put are extremely varied. Probably one of the most important uses is in the construction of floors. In this position concrete has been largely used, but generally with almost entire neglect of its considerable resistance in compression. Thus economy is evidently to be expected in this application of its use.

Masonry walls are made sufficiently massive to ensure that the various thrusts which must of necessity come upon them will without doubt bring the resultant thrust within the middle third of the thickness ; thus avoiding tensional stress, which bricks or stone blocks set in weak mortar are only slightly capable of resisting. In the case of armoured concrete, bending stresses are no longer to be feared, and the thickness of a wall may with safety be considerably reduced. The advantage gained in this direction is still more evident in the case of arches and their abutment, where the weight may often be reduced to a third or a quarter of that necessary in stone.

As compared with steel construction, the use of armoured concrete is particularly advantageous in its complete protection of the metal, in the absence of vibration, and in the freedom of condensation upon its surface, besides its economy in cost of construction.

It must be borne in mind that the many advantages in the use of armoured concrete can only be attained by careful design and by still more careful supervision.

CHAPTER II

ARMOURED OR REINFORCED CONCRETE: GENERAL PRINCIPLES OF THE VARIOUS SYSTEMS

(*Contributed by P. R. Strong*)

General Principles.—The general arrangement of reinforcement in the construction of floors and pillars may be seen in Figs. 23 and 39. It will be observed that floor slabs and beams are reinforced with rods close to their lower surfaces, except where beams pass over pillars or where secondary beams are supported by primary beams; or again, where slabs are supported by beams—in which positions the rods are transferred to the upper parts of the concrete, for it is here that the tensile stress is then found.

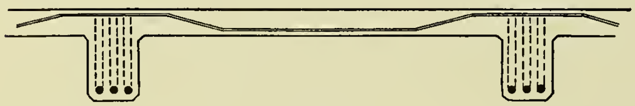


Fig. 24.

A section through a floor slab and floor beam is shown in Fig. 24, in which the slab is seen to be one with the beams. Fig. 25 shows another method that may be adopted, in which the beams are distinct from the slabs, the latter being moulded in advance and simply resting upon the beams. In this case, as the slab is not continuous, the reinforcement is not transferred to the upper surface over the supporting beams. The method shown in Fig. 24 has the advantage that the beam is of tee sections, and that the concrete of

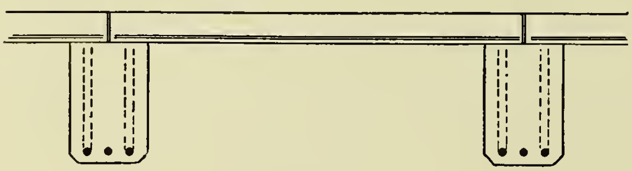


Fig. 25.

the floor slab assists in taking the compressional stress, while the concrete in the tensional portion of the beam may be reduced to the minimum; while at the same time the fact that the slab is continuous over its supports affords to it additional strength.

Yet another system, that of Stuart's Granolithic Co., designed by Mr. E. P. Wells, is illustrated in Fig. 26. Continuous rods, carried over the beam, are introduced in the lower part of the floor slabs, which are generally 4 inches thick, the rods being $\frac{3}{8}$ inch diameter, spaced at such distances apart as will give the necessary total of reinforcement. The concrete is filled in, bay by bay, to half-way across each girder, further reinforcing rods being introduced, as shown in Fig. 26, to connect the bays and take up the tension near the top due to the continuous nature of the rodding. The lengths of these rods vary as may be necessary, and each is cranked

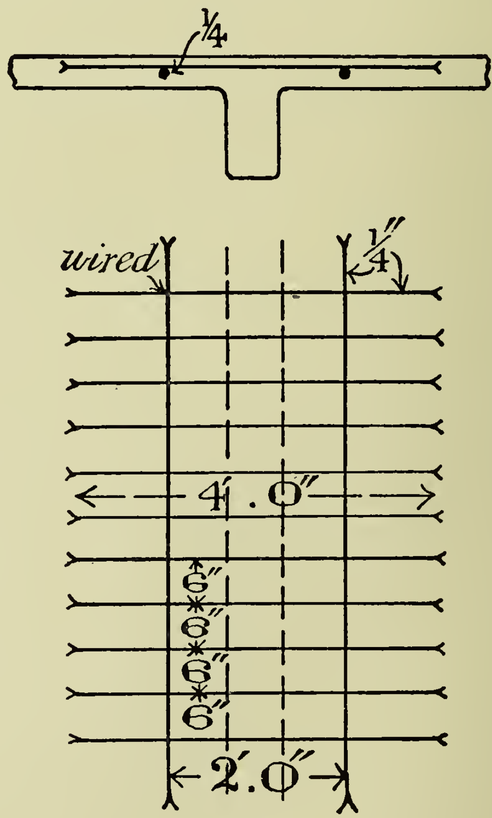


Fig. 26.

or split at the ends to give it a firm grip on the concrete. The longitudinal rods, parallel with the beam, are only introduced to distribute any fixed load or the effect of unexpected impact over several working rods, and are generally placed at 12 inch centres.

It will be noticed that the pillars also are reinforced with rods, and it might be thought that this was unnecessary in a pillar properly loaded, in which there should be no tensile stress; but the rods serve a further

purpose, for, besides taking part in the resistance to the load and thus reducing the section of the pillar, they help to bridge over any variations in the strength or elasticity of the concrete, and thus give the material more uniform resistance.

Shearing Stresses.—Besides the rods embedded in the slabs and beams there are also vertical members, as in the Hennebique and Wells systems, or inclined members, as in the Kahn system.

In Volume IV. it was shown that besides the simple tensile and compressional stresses in beams there exist shear stresses, both horizontally and vertically, the average horizontal stress being equal to the vertical

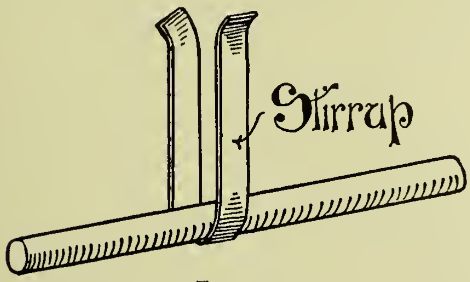


Fig. 27.

shear stress per unit of length at all points in the length of the beam. Concrete alone is found to have insufficient resistance to shear, and it is for the purpose of resisting the horizontal shear that the vertical or inclined stirrups are used. Fig. 27 shows the Hennebique stirrup. It is common to use sufficient of these stirrups to take the whole of the horizontal shear, but their employment at the same time materially assists the concrete itself to resist the same stress, in that they tie the layers of concrete together.

The greatest horizontal shear is at the neutral axis, and in a rectangular beam has been shown to be equal to $\frac{3}{2}$ of the average shear. The horizontal shear there-

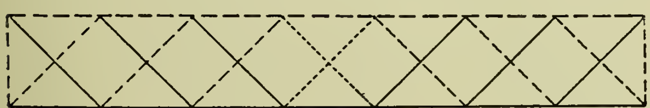


Fig. 28.

fore has greater effect than the vertical shear, while the use of vertical members is particularly necessary in the case of the tee beam; for at the neutral axis, where the shear stress is greatest, the section is reduced to the minimum.

It is common to make no special allowance for the resistance to vertical shear, and in this case it has to be met by the concrete and increased stress upon the tensional rods. In order to meet both horizontal and vertical shear it would be well to place the stirrups in an inclined position, so that they will offer their section in both directions. The horizontal and vertical shear may, in fact, be regarded as the horizontal and vertical components of diagonal, compressional, and tensile stresses. This is clearly illustrated by the lattice girder, as in Fig. 28, in which all tensional members are represented by full lines, while those in compression are shown in stout dotted lines, the unstressed members being indicated by small dots.

In a rectangular beam the tensile components of the shear stresses, together with the longitudinal tensile stresses, produce resultant tensile stresses acting in curved lines, as indicated by the full lines in Fig. 29, while the compressive stresses produce similar resultant compression lines as indicated in dotted lines. The effect of the tensile stresses when the beam is loaded to failure is to produce cracks along surfaces at right angles to the tensile stresses, for it is here that the maximum intensity of tensile stresses will be met. That is to say, cracks will be produced along the dotted or compressional lines. Fig. 30 clearly shows this effect. At the centre of the beam, where the ten-

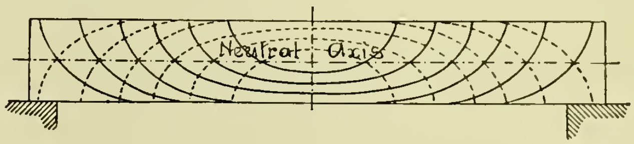


Fig. 29.

sile stresses are horizontal, the stress has been entirely met by the horizontal reinforcement; but at the ends, where they take an upward direction, cracks have been produced due to the absence of vertical reinforcement.

The curved disposition of the tensile stresses could

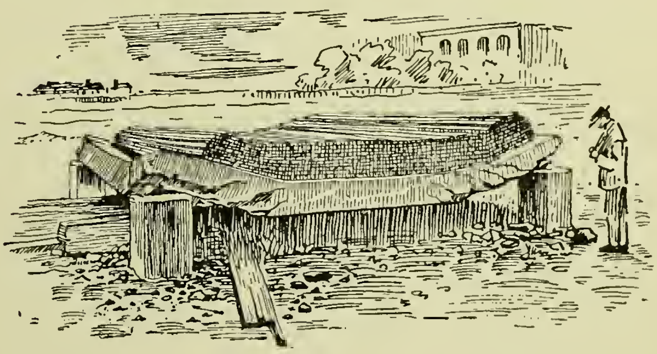


Fig. 30.

probably be most thoroughly met with the greatest economy of metal by the use of many small rods following these lines; but this method is found to be impracticable, and the many and various "systems" that are in use, or that have been used, are merely so many solutions of the most practicable method of meeting these stresses.

It is clear that if stirrups be used in conjunction with horizontal members, to resist the curved disposition of tensile stress, some rigid connection is necessary between the two. This connection is generally supplied by the "adhesion" of the concrete to the metal, and under ordinary stresses there is little doubt that this is generally sufficient to meet the case; but if they are rigidly connected the beam will be doubly secure in

this respect. This condition is met by the "Kahn trussed bar" (Fig. 31). This bar is rolled with projecting wings on either side, which wings are sheared and bent up to form the inclined reinforcement. The condition is likewise met to some extent in the Hennebique system by the sloping up of the reinforcement to pass over the supports; and most frequently by the Wells system, to be explained immediately.

Systems.—As before stated, the various systems all endeavour to meet the same theoretical requirements

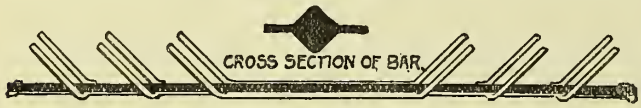


Fig. 31.

in the most simple and practical manner. Many firms secure patentable systems by the employment of special forms of reinforcing bars. For instance, the Ransome system, much used in America, employs a reinforcement consisting of a square rod twisted throughout its length, the object being to prevent its slipping in the concrete, while at the same time the elastic limit of the metal is considerable increased by the process. Fig. 32 shows another special bar by the Patent Indented

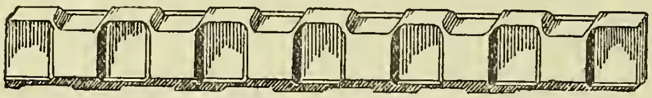


Fig. 32.

Steel Bar Company Ltd. Other systems again employ special arrangements of bars of ordinary section.

The Hennebique System.—A system which has been much used in England is that of M. Hennebique (Fig. 23), the special feature in this being the hoop-iron stirrup (Fig. 27). Fig. 33 shows the general arrangement of rods and stirrups in a beam. It is seen that the reinforcement consists of two rods vertically over one another, and that where they pass over the supports the upper rods are bent up to the upper surface. Fig. 34 shows a detail at a point where a beam passes over

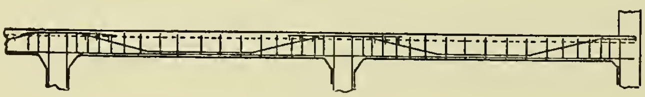


Fig. 33.

a pillar. The join in the rods is formed by simply overlapping them, their ends being slightly split; and in order to connect them more intimately with the concrete small stirrups are placed about them at these points. The beam being in the form of a tee, the necessary area of concrete to resist compression is provided in the horizontal arm, while a comparatively small area exists in the lower portion of the beam. Over the supports, however, where the stresses are reversed, the concrete to resist compression is reduced to that in the lower portion of the beam. It is assisted, however, by the lower reinforcing rods, which are carried straight through, and also to some extent by the splayed portion at the top of the pillar.

A detail section through beam and slab is shown in Fig. 35. Small stirrups are seen to be used in the slabs as well as in the beams. Where either slabs or beams are freely supported the rods are not bent up as

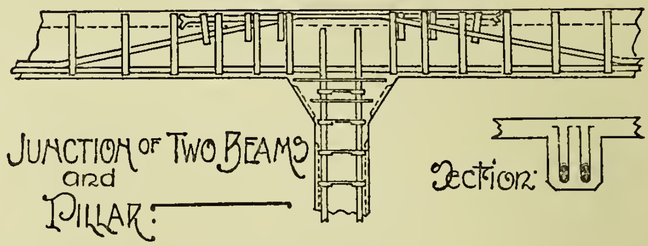


Fig. 34.

shown in these illustrations, but are carried straight along the lower surface.

The reinforcement of pillars may be seen in Fig. 34, while a detail showing the wire ties which bind the vertical rods may be seen in Fig. 36. The splayed portion at the head of the column is further reinforced by horizontal rods (Fig. 34).

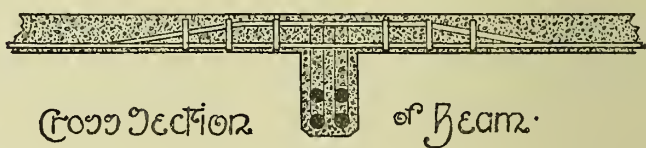


Fig. 35.

Coignet System.—In this system the principal reinforcement is carried along the whole length of the lower surface of the beams, while smaller bars are introduced near the upper surface in order that, with the addition of stirrups, the tensile and compressional portions of the beam may be connected in a practical and mechanical manner (see Fig. 37). These upper or secondary bars also assist in resisting the compressive stress and improve the resistance of the con-

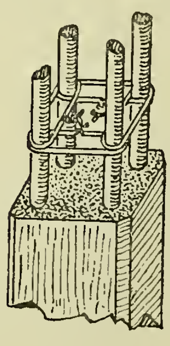


Fig. 36.

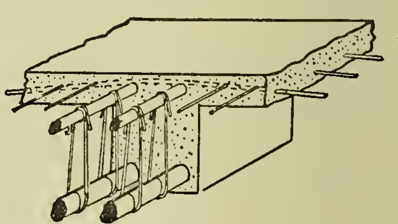


Fig. 37.

crete itself as mentioned elsewhere. All intersections between bars and stirrups are secured with annealed wire, thus producing a framework with a certain amount of rigidity, which, when formed, can be lifted up and fixed in position in the moulds, and the concrete can then be filled in and packed about it.

Slabs of large span are constructed in the same manner as are beams, as in Fig. 38, while thinner

slabs, 3 or 4 inches thick, supported by ribs only a few feet apart, are formed as in Fig. 39. Annealed

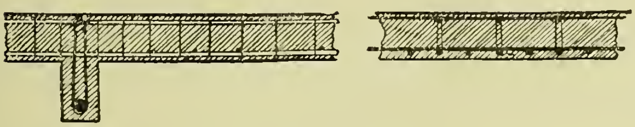


FIG. 38.

wire binding is used at every other intersection of the rods of slabs.

Kahn System.—Figs. 40 and 41 show the general adaptation of the Kahn trussed bar, a detail of which

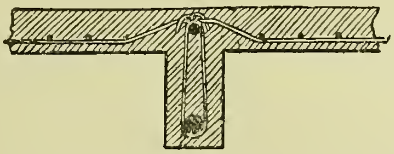


FIG. 39.

was shown in Fig. 31. The sizes of bars used are given in the following table:—

Section of Diamond.	Width across Wings.	Thickness of Wings.	Weight per Foot Run.
Inch. Inch.	Inches.	Inch.	Lbs.
$\frac{1}{2} \times \frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{3}$	1.4
$\frac{3}{4} \times \frac{3}{4}$	$2\frac{3}{16}$	$\frac{3}{16}$	2.7
1×1	3	$\frac{1}{4}$	4.8
$1\frac{1}{4} \times 1\frac{1}{4}$	$3\frac{3}{4}$	$\frac{1}{4}$	6.9

The diagonals are ordinarily placed opposite one another, and in deep girders they thus come rather far apart To avoid this they may be staggered,

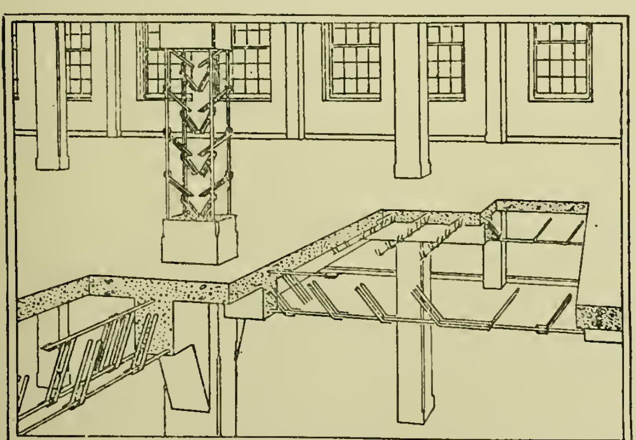


FIG. 40.

being placed alternately on either side of the bar. In this way diagonals 24 inches long may be obtained 12 inches apart. Where a beam or slab passes over its support, reversed bars are used with their diagonals sloping downwards, as may be seen in Figs. 40 and 61. In deep girders the straight reinforcement along the bottom may be supplemented by a shorter bar sloping upwards from the centre, as shown in the top illustration of Fig. 41.

Fig. 42 shows the Kahn system of reinforced hollow tile floor. This floor is light, produces an even surface on the under side, and gives improved resistance to the transmission of sound. The construction is extremely simple, for the secondary beams, which take the form of joists at 10 to 16 inches between centres, are formed between hollow tiles, which are simply laid upon a flat centering. The tiles are made from 4 to 12 inches deep. Floors of this description may be constructed up to 25 or even

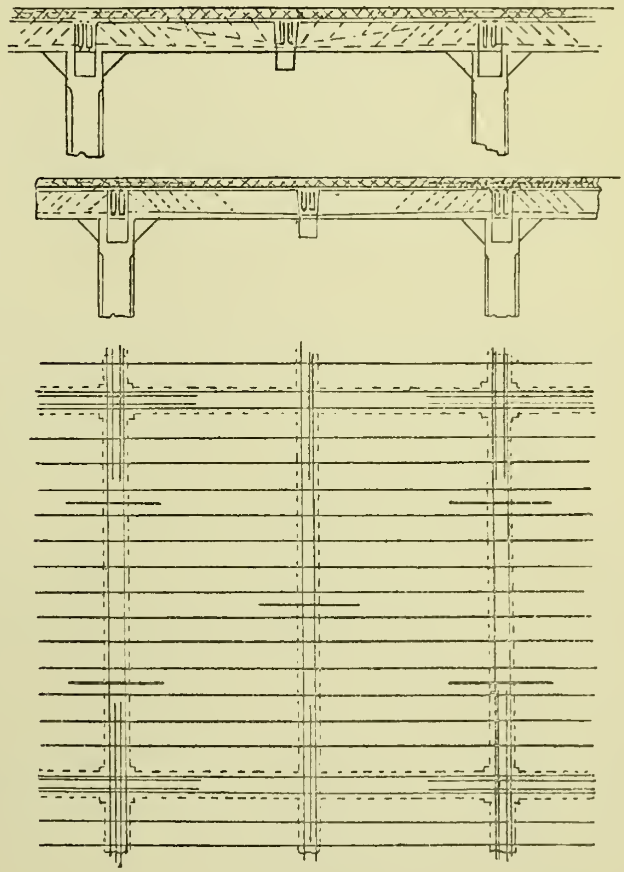


FIG. 41.

30 feet span, while primary beams are formed of the usual construction.

Wells System.—The Wells system, of which the floor slabs were illustrated in Fig. 26, consists in its essence upon the arrangement of the main reinforcements of the beams. The rods, as shown in the general drawing (Fig. 43) and the detail (Fig. 44), are twin, each pair connected by a very short web, and so somewhat like a pair of dumb-bells in section. These lie either side by side or above one another at the bottom of the girder along the centre of the span; but the web is cut back to the point of contraflexure, and one of the twin rods bent up to pass over intermediate supports. The two rods thus separated are again connected by strap

hangers of small bar section, indented so as to cling to the concrete, these straps being twisted round each rod. The rigidity of the Kahn system is thus obtained, as the steelwork of each girder can be built up before being lifted into place and the concrete inserted, with the theoretical rodding of the Hennebique, and without any difficulty being experienced in keeping the bonders or stirrups in place as the concrete is filled in or while it sets; any additional vertical bonders being driven into the concrete immediately before setting commences, and keeping their places from the outset owing to their indented form.

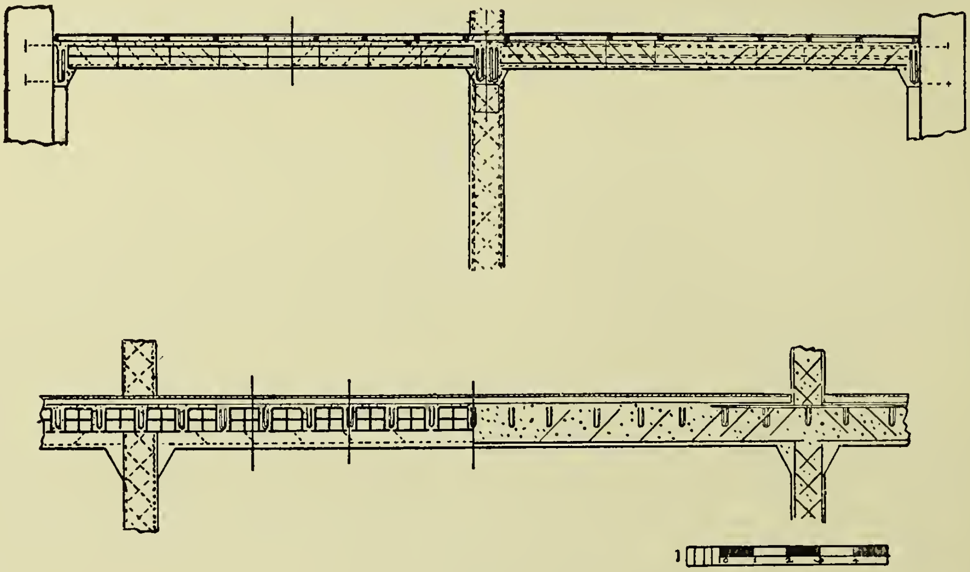


Fig. 42.

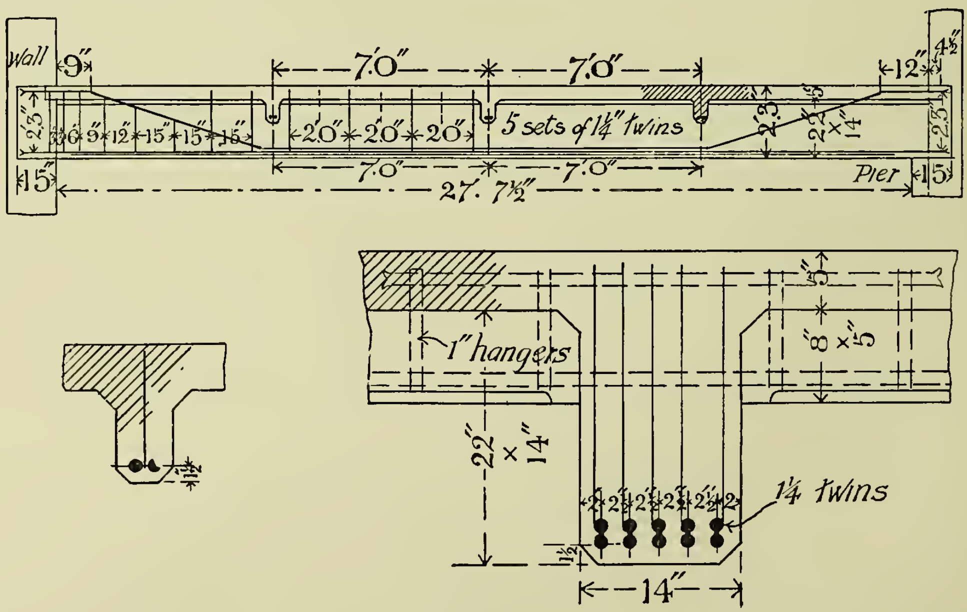


Fig. 43.

Expanded Metal.—For illustration and description of this, see page 185, Vol. IV. This material is of great use in the construction of armoured concrete, particularly for the production of slabs. It produces a thoroughly even distribution of reinforcement, while it offers resistance in both directions. A further advantage in the use of this material is that the tensile stress upon the metal tends to close up its meshes, thus producing compressional stress upon the concrete at right angles to the tensile stress, the effect of this being to improve the elastic qualities of the concrete.

A Hollow Floor.—A hollow floor may be constructed as indicated in Fig. 45, the ceiling slab and the beams being formed on a flat centering, while the floor slabs are moulded in advance and are set in position. The assistance of the floor slab in taking the compressional stress in the beam is lost by this construction, and to make up for this a compressional

reinforcement is introduced, while the considerable advantages of a hollow floor and flat ceiling are gained.

ROOFS.—Flat roofs are constructed on precisely the same principle as are floors, while the slight slope necessary is readily provided in this material, and there need be no question as to the efficiency of the protection of the metal against fire. By giving the roof a fall in both directions from the centre line the cross beams may be given greater depth at the centre, where the greatest bending moments are to be met.

Fig. 46 shows the construction of a roof on the

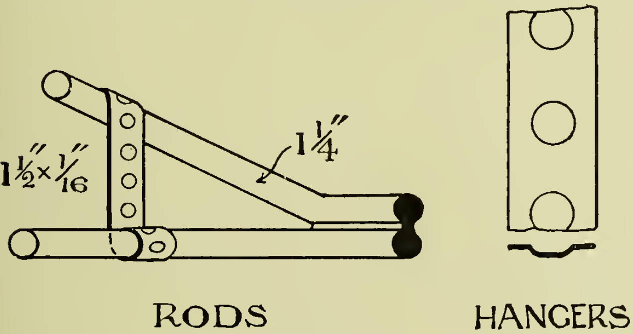


FIG. 44.

Kahn hollow-tile system. The simple form of the centering is here visible.

FRAME BUILDINGS.—The most economical method of constructing a building in armoured concrete follows precisely the same principle of concentrating all loads upon evenly distributed points as that described under the head of "Steel Frame Buildings" (see Vol. IV.), with the following advantages: The structural load-carrying framework need not be encased either for protection or for appearance sake, although if architectural effect is desired a stone facing may be applied here as in the case of steel frame buildings. With

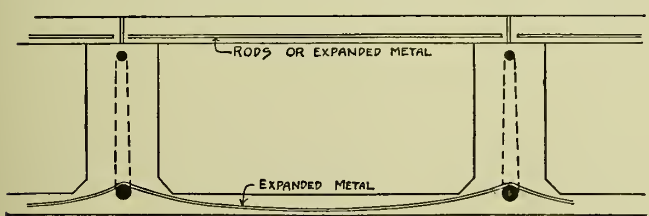


FIG. 45.

proper care and thorough supervision there is no fear of the failure of the building from the corrosion of the metal. The material particularly lends itself to the satisfactory protection of the metal from fire, and the difficulty of properly protecting the spandril framing is completely overcome. The rigidity of the joints between the various members is necessarily good, and needs no special provision beyond the splaying out of pillars at these junctions. Variations in the original design can be readily effected, while in the case of steel framing this is governed by the steelwork already supplied or ordered.

MOULDS.—The construction and arrangement of the moulds call for much ingenuity, in order that they may be thoroughly rigid, that they may cause as little obstruction as possible, that the damage to the wood

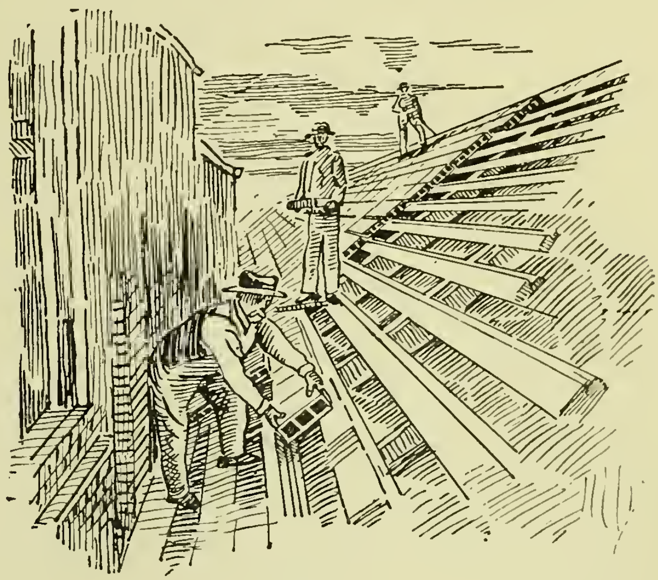


FIG. 46.

may be small, and that it may be possible to re-use the moulds as often as possible. Skilful arrangement will expedite erection and considerably reduce the cost of this part of the work, which forms a large item in the

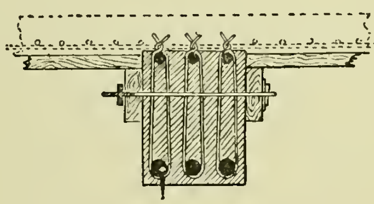


FIG. 47.

total cost. The rigidity of the moulds is particularly necessary, in order that work which is being carried on may not cause vibration in concrete which has recently been put in place; for it is found, as might be expected,

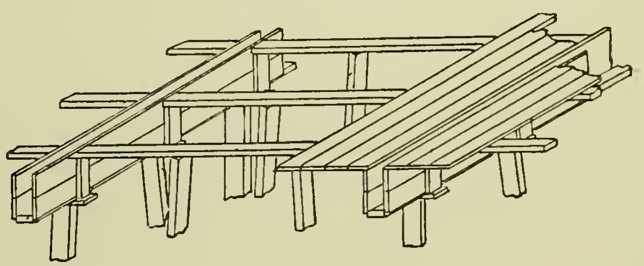


FIG. 48.

that vibrations in the concrete, while setting, very seriously affects the strength of the resultant material.

Fig. 47 shows an arrangement of centering adopted with the Coignet system. The beam here shown has been moulded in advance, and when set in position it

supports the slab centering. Fig. 48 shows the construction of centering, also used with the Coignet system, when the beams are not moulded in advance.

The moulds about the sides of walls or pillars and on the vertical sides of beams should be left in position for not less than 48 hours after moulding. The centering under floor slabs should be left in position for at least a week, while props supporting the beams and slabs at the centres of their spans should be left in position as long as possible ; but not less than one month.

CHAPTER III

CONCRETE AND ITS PROPERTIES

(*Contributed by P. R. Strong*)

Materials.—Cement, in binding the aggregate together, may perhaps be considered to be the most important ingredient of concrete, and none but the best slow-setting Portland cement should be used. The quality should be undoubted, and every consignment should be tested by all the tests allowed for in the specification. The quality of the cement may well be specified to conform with the specification of the Engineering Standards Committee.

The aggregate should have strength at least as great as that which the cement alone will eventually possess. Aggregate containing pieces varying up to those of moderate size make the strongest concrete, but for armoured concrete the size must be small on account of the thinness of the members, and in order that the reinforcement may be thoroughly surrounded. Thus for beams the aggregate should be capable of passing a 1 or 1¼-inch ring in all directions, while for floor slabs this should again be reduced to ½ inch. The properties of various aggregates as regards fire resistance has already been discussed. Aggregates of sharp hard nature, such as broken stone of good quality, make the strongest concrete, while the strength of coke-breeze concrete may be only one-half to a quarter of that similarly formed with broken stone, and may be even less than a quarter, so that this material is evidently unsuitable for pillars or beams or wherever heavy loads are to be carried.

Sand, which must be hard and sharp, should preferably be of coarse quality—that is to say, it should be of the nature of grit.

Water may possibly contain chemical impurities which will deleteriously affect the setting of the cement, and unless the water is of known quality it should be analysed.

All materials should be thoroughly clean, for dirt of fine nature will prevent the proper adhesion of cement to aggregate, or of cement to cement. All aggregate and sand, unless thoroughly clean, should be washed, and dirty water should on no account be used.

Proportions.—It is of the first importance that the mixing of concrete should be in correct proportions, and this part of the work being in the hands of labourers, the exact proportions of all ingredients, cement, stone, sand, and water should be laid down, and the use of accurate measuring boxes should be insisted upon.

The strength of concrete depends largely upon the amount of really hard aggregate that can be put into a given volume. There is little doubt but that the strongest concrete could be made with material varying evenly in size from pieces of moderate size down to the size of the grit grains, the spaces between the larger portions being filled by those of smaller size, and the whole being cemented together with cement. That is to say, the concrete would consist of two ingredients only, namely, aggregate of varying size and cement. This condition is not easily met in practice, so that the mixture is generally regarded as consisting of aggregate of moderate size embedded in a mortar of cement and sand; and on account of the usual method of proportioning the materials by volume, the latter method may appear on the face of it to produce an equally strong or even stronger material, but this will in reality be obtained with an increased proportion of cement, as will be shown.

It is evident that, in order to form a solid mass, the quantity of cement and sand should be just sufficient to fill the interstices caused by the coarseness of the aggregate. The extent of these interstices may be found by filling a receptacle of known capacity with the aggregate, by then ramming it, and by measuring the quantity of water required to bring its surface up to the level of the top of the aggregate. If the aggregate be composed of coke-breeze, broken brick, or other porous material, it must be thoroughly soaked before making the experiment. The volume of the voids in proportion to the volume of the aggregate, as ordinarily measured, is thus found, and this quantity, increased by about 10 per cent. of the total volume to ensure the thorough flushing of the work, gives the necessary amount of mortar. This volume is constant for the particular aggregate, no matter what strength is required: the strength of the concrete must be regulated by varying the strength of the mortar.

For example, if the extent of the voids in a particular aggregate when rammed is found to be 45 per cent. of its original volume, adding 10 per cent., the proportion of mortar necessary becomes 55 per cent. As cement and sand when mixed with water will decrease in bulk by approximately 20 per cent., their amounts must be increased by a quarter, and the volume of mortar will

be $55+\frac{55}{4}=69$ per cent. Then if the mortar is to be composed in the proportion of 1 : 2, the volume of aggregate required with these three parts of mortar $=\frac{100\times 3}{69}=4.35$; that is to say, the proportions should be 1 : 2 : $4\frac{1}{3}$.

1 : 2 : 4 is a very usual proportion with ordinary aggregates, and has been found by experiment to yield high compressive resistance.

Considering an aggregate of the nature assumed above, as long as the mortar is mixed in the proportions 1 : 2, a variation in the volume of the mortar, whether in the way of increase or decrease, will diminish the resistance of the concrete. Supposing that it be desired to form a stronger concrete with mortar mixed with cement and sand in equal proportions, the aggregate being the same as was assumed above, the volume of the mortar must remain the same, and the proportions will become $1\frac{1}{2}$: $1\frac{1}{2}$: $4\frac{1}{3}$, or say 1 : 1 : 3.

If stone and sand be intimately mixed the resulting mixture will be found to take little if any greater space than that taken up by the stone alone. Thus if a concrete of the proportions 1 : 2 : 4 be taken and the sand and stone be mixed, the proportion will become one of cement to four of a mixture of sand and stone. Therefore if the aggregate consist of a natural mixture in these proportions, the concrete mixed in the proportions of one part of cement and six of this mixture will have considerably less cement in proportion to the mass of finished concrete than would be the case if the sand and stone were measured separately. Thus when an aggregate itself contains sand it is impossible to proportion the ingredients accurately, and for this reason the apparently extravagant process of screening out the sand is often resorted to, and is the only way by which the proper proportions can be continuously and mechanically measured.

There exists much confusion as to the proportions intended by the expression 1 : 6, some reading this as 1 of cement to 2 of sand and 4 of stone, while others will read it as 1 of cement to 6 of stone, the sand being added to the cement in the proper proportion. To obviate all confusion the measure of each ingredient should be specified as 1 : 2 : 4 ; while it should be laid down that measuring boxes shall be used for each ingredient.

Quantity of Water.—The question as to the correct quantity of water has called forth much unnecessary controversy and unconsidered faddism. Mixtures are very generally known as "wet" and "dry," some preferring to use the concrete in an almost sloppy condition, while others add the least possible amount of water. The very terms "wet" and "dry," indeed, suggest excess in either direction.

All concrete, no matter how mixed, will always contain cavities, and the best mixing will be that which reduces the amount of these cavities to the minimum.

If a "dry" mixture be used, a greater amount of mixing and turning over will be necessary to thoroughly coat the aggregate with the mortar, while there is every possibility that part of the cement will not receive sufficient water for its proper setting. The mixture, however, in this state is easily rammed, and will shrink much in the process.

If a "wet" mixture be used the fluidity of the mass will result in a fair degree of consolidation without the employment of ramming ; and indeed, if the mixture be very wet, ramming will be impossible. The excess water distributed throughout the mass must leave cavities on drying out ; but while the voids in concrete mixed dry may take the form of actual cavities, those in concrete mixed wet will be distributed throughout the cement, which will be left of a porous nature, and although the material is devoid of any large cavities the strength is certainly much reduced.

There is little doubt that concrete made with only just sufficient water to thoroughly wet all the cement will, if mixed with great care and well rammed, produce the strongest concrete ; but the necessary degree of care cannot be ensured in actual work.

It seems reasonable, then, to use sufficient water to leave no doubt as to the thorough wetting of the cement, which will allow efficient mixing to be easily accomplished, and at the same time will not produce a concrete too wet to be thoroughly rammed. Any water in excess of this may be considered as deleterious to the production of the strongest concrete.

A shingle or similar aggregate, besides not permitting such perfect adherence with the cement as will broken stone, at the same time, if fairly wet, becomes too fluid to be efficiently rammed. In certain cases it is not possible to thoroughly ram concrete on account of its position in the work, and in such cases a wet and fluid mixture will give the best result.

In armoured concrete, as regards the thorough protection of the surface of the rods, a moderately wet mixture is desirable to ensure a cement coating ; while, on the other hand, closer adherence between metal and concrete is obtained when excess of water has not been used.

The Properties of Concrete.—The properties of concrete, its resistance to various forms of stress, its elasticity and expansion, must all depend upon the proportions of the concrete and the nature of the component materials, the amount of water, the extent of mixing and ramming, the expedition with which the work is effected, the absence of vibration during setting, and the age of the finished concrete. However, before calculations can be entered upon to find the necessary dimensions of parts it is first necessary to know something of the behaviour of concrete under stress, and to fix values on which the calculations may be based. For important works it will be advisable to make tests with the materials to be used, mixed and treated in the same manner as they will

ordinarily be treated in the work; for very different results may be obtained if the concrete to form the test pieces be mixed in small quantities in a laboratory.

COMPRESSION.—For concrete mixed in the proportions of 1 : 2 : 4, carefully mixed with good materials and hard stone aggregate, the crushing strength may be taken as roughly 1 ton per square inch at the end of 1 month or 6 weeks after mixing. The strength increases rapidly at first, and more and more slowly as the age of the concrete increases. At the end of six months the crushing strength will probably be half as much again as that indicated above. After concrete has been made for about a year the strength increases very slowly but indefinitely.

The age at which the concrete may be called upon to carry its full load will generally be uncertain, but for safety it may be assumed that this will take place after 4 to 6 weeks, and the crushing resistance may be taken as 2240 lbs. per square inch.

The strength of various mixtures is found to vary much as does the proportion of the cement in the mortar. Thus if the proportion of cement and sand in the concrete be 1 : 1,—*i.e.* 1 of cement in 2 of mortar, the crushing resistance of the concrete will probably be nearly twice as great as if the mortar is composed of 1 of cement to 3 of sand (or 1 of cement in 4 of mortar).

FACTOR OF SAFETY.—In deciding upon the factor of safety for steelwork it was shown that the elastic limit, which is roughly half the ultimate strength, must never be reached, and that this value was halved for safety, thus producing a factor of safety of 4 on the ultimate resistance. In the case of concrete the elastic limit cannot be clearly defined as in the case of steel, although attempts have been made to fix its value; but even if such a point exists the advantage gained in deciding upon it will be largely nullified by the use of a further large and arbitrary factor. In using a heterogeneous material such as concrete it is obvious that a larger factor should be used than when dealing with steel. It is the usual practice, then, to employ a factor of safety of 5 or 6.

SAFE LOAD IN COMPRESSION.—Taking an ultimate load of 2240 lbs., and applying a factor of safety of 5, the safe load becomes 448 lbs. per square inch; or using a factor of 6, it becomes 373 lbs. In order to obtain a round number, the safe compressional load will here be considered to be 400 lbs. per square inch, assuming that the concrete is 1 : 2 : 4 stone concrete of good quality and carefully mixed.

For concrete of coke-breeze, one-third of above value may be taken; or, say, 130 lbs. per square inch.

The above safe values apply to members in direct compression only. For beams, they may be increased by about 25 per cent.; but this will be considered later.

TENSION.—The resistance of concrete in tension is generally accepted to be $\frac{1}{10}$ of that in compression, and, considering the same qualities as assumed above, the tensile resistance becomes $\frac{2240}{10} = 224$ lbs. per square inch ultimate resistance, or $\frac{400}{10} = 40$ lbs. per square inch safe tensile stress. This value will, however, seldom enter into the calculations of armoured concrete.

SHEAR.—Much doubt exists as to the resistance of concrete to this form of stress owing to the difficulty of producing simple shear. The ultimate stress is variously estimated at 120 to 440 lbs. per square inch, and using a factor of safety of 6 the safe stress becomes 20 to 73 lbs. The first of these values is undoubtedly unnecessarily low, and there is not much doubt but that shear resistance is at least as great as the tensile resistance. The Prussian Government regulations allow 64 lbs. per square inch, while the New York regulations allow 50 lbs. per square inch; and it would seem that the latter allowance may safely be made.

"ADHESION" TO METAL.—The resistance to sliding between concrete and reinforcing metal varies considerably, according to richness and wetness of concrete, upon the condition of the surface of the metal, upon the length of the embedded metal, and also upon its shape and sectional area. For rough rods just as supplied the resistance is apparently 200 to 500 lbs. per square inch; and these values may be halved if the surface of the metal is turned smooth. This resistance per square inch decreases with the length of the embedded metal, while it increases as the sectional area of the metal increases. The resistance is distinctly improved if the surface of the metal is slightly rusty, and, as was pointed out in Chapter XVII. Part II. Volume IV., this will have no bad effect upon the preservation of the metal, while the reverse even seems to be the case. Most regulations allow the same resistance to sliding as to shearing, and the safe resistance thus becomes 50 lbs. per square inch.

There is little doubt that the resistance to sliding is great enough under all ordinary stresses in beams, but it does not follow that the same factor of safety is allowed in this case. Many patent reinforcing rods have been introduced to increase this resistance, such as that used in the Ransome system, which is a square bar twisted spirally, and also the patent indented bar and the Kahn bar already described.

MODULUS OF ELASTICITY.—The results of experiments show largely divergent results on this property, while for any particular concrete it is greatest at low pressures and decreases as the load increases. Apart from extreme results, values are obtained varying from 2,500,000 to 4,500,000, while 3,000,000 may be considered as a safe average value. The actual value matters little, but it is the ratio of the modulus of elasticity of steel to that of concrete which is of importance in calculation. The modulus of elasticity of steel was given in Volume IV. as 13,500 in inch-ton units;

and, multiplying by 2240, this becomes 30,240,000 in inch-lb. units. Representing the latter by E_s and that of concrete by E_c, and taking the value of E_c as 3,000,000, $\frac{E_s}{E_c} = r = 10$ approximately; that is to say, to produce a certain strain in steel will require a load per square inch 10 times as great as that required to produce the same strain in concrete.

The value 10 is recommended for adoption by many authorities. The Prussian Government regulations state that these moduli are to be taken as 1 : 15, while the New York regulations fix the ratio as 1 : 12.

The Properties of Steel.—These were discussed in Chapter IV. Part II. Volume IV. No punching, riveting, or similar work is done upon the metal in the case of armoured concrete, and therefore there is no need to take very low values. Putting the value in lbs. in order to conform with the allowable stress upon concrete, the safe values for steel may be taken as—

Tension, 16,000 lbs. per square inch.
Shear, 12,000 lbs. per square inch.

Effect of Temperature.—The coefficient of expansion of concrete is approximately 0.0000055, while that of steel is 0.0000066. The difference is apparently sufficiently small to have no appreciable effect upon the adherence between metal and concrete, while the small conductive power of the latter prevents the metal from being affected by any sudden or local rise of temperature.

Expansion and Contraction.—Concrete shrinks when setting in air, the effect being greater the richer the mixture be in cement. When setting under water the reverse is the case, and here expansion takes place. The greater part of the contraction or expansion takes place during the first week after mixing, and the variation is small at the end of a month.

The shrinkage of concrete when drying in air places the reinforcement in compression and the concrete itself in tension, with the result that before the concrete is put in compression and the steel in tension the stresses have to be reversed. The effect of this is on the side of safety, and its extent need not be considered.

CHAPTER IV

ARMOURED OR REINFORCED CONCRETE—BEAMS

(*Contributed by P. R. Strong*)

Bending Moments.—Armoured concrete lends itself particularly to the construction of beams which are continuous over their supports and of beams with fixed ends. As pointed out in Volume IV., the fixing of ends cannot be entirely relied upon, and it is usual to consider the bending moment at the centre of such beams as $\frac{wl^2}{10}$, while the BM at the supports should be taken as not less than $\frac{wl^2}{20}$. In the case of continuous beams carrying a live load, one bay alone may be fully loaded, when the BM at the centre of this beam will be greater than that given in Chapter IV. Part II. Volume IV., and it may well be assumed that the BM at the centre of each span is $\frac{wl^2}{12}$. When, however, a dead load only is carried the BM shown in Fig. 70, Volume IV., may be considered as appertaining; but for sake of uniformity it will seldom be advisable to alter the section of the beam in accordance with these variations in BM, nor the section of the pillars to the varying reactions.

Tensile Stresses.—At the outset it will be assumed that the resistance of the concrete to tension is negligible. As a general rule, however, it is probable that the concrete aids in the tensile resistance to an appreciable extent, and it is maintained by some authorities that it offers resistance right up to the breaking-point of the beam, even when strained far beyond the point at which it would naturally break, this property being produced by the reinforcement, which prevents excessive elongation at one particular point and spreads the effect of strain throughout the length of the beam. It is common knowledge that concrete when setting and hardening in air will contract, and if prevented in this it will crack. This is largely overcome in armoured concrete by the distributing action of the reinforcements just mentioned; but, considered generally, the tensile resistance cannot be relied upon, while, by neglecting it, the safety of the beams will be increased. Thus in the considerations of the longitudinal stresses in beams the concrete on the tensile side of the neutral axis may be regarded as non-existent, as shown in Fig. 49.

Strain.—In the consideration of beams (Chapter II. Part II. Vol. IV.) it was assumed that on the beam being deflected the extension and compression would be as illustrated in an exaggerated form in Figs. 49 and 62 in the same Volume, the section plane before bending remaining a plane surface after bending. On this assumption strain is proportional to the distance from the neutral axis; and, as it was shown in that case that stress was proportional to strain, intensity

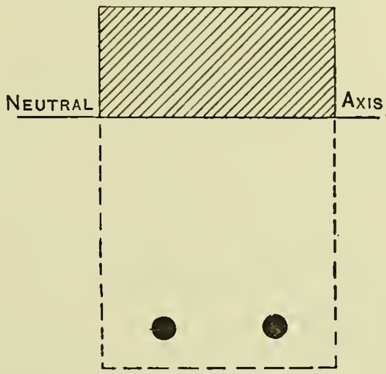


Fig. 49.

of stress also varies directly as the distance from the neutral axis.

The assumption that a plane section remains a plane section after bending will be again assumed here, although its absolute truth is more than doubtful; for even in the case of a homogeneous material the shearing

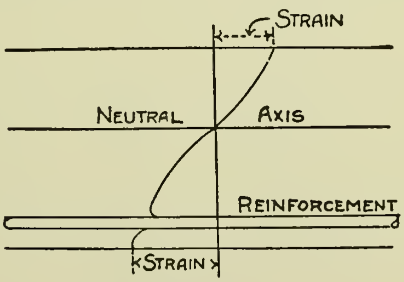


Fig. 50.

stress between layers will produce a wavy surface, while the shearing stress between reinforcement and concrete produces a hollow in the originally plane surface. The result of deformation probably takes somewhat the form shown in Fig. 50. However, the assumption may be most conveniently adopted, and is sufficiently accurate, while the result will be on the side of safety.

Disposition of Stress. — When considering steel, stress was shown to be proportional to strain, with the result that intensity of stress increases evenly from zero at the neutral axis to its maximum at the extreme fibre. In the case of concrete this law of proportion does not hold, the stress becoming less in proportion to the strain as the latter increases; that is to say, the modulus of elasticity decreases as the stress increases. Fig. 51 shows the approximate form of the stress strain curve. Thus in the case of a rectangular beam,

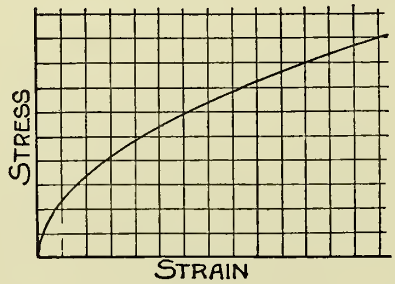


Fig. 51.

as the strain increases regularly from neutral axis to outer fibre, the area representing total compressional stress (Fig. 52) is bounded by the same curve as that in Fig. 51. This curve is found to follow very closely the parabolic form for the range of stress applicable in practice. Many prefer to consider the stress as being directly proportional to the distance from neutral axis, as in the consideration of steel (Fig. 53); but the parabolic form is certainly nearer the truth, while its application introduces no greater complication; for the

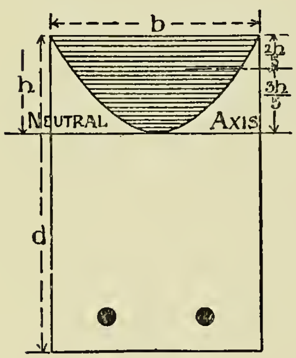


Fig. 52.

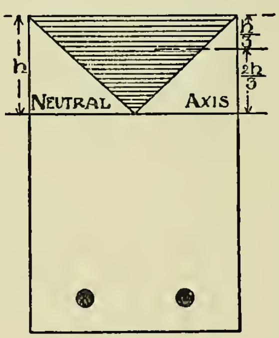


Fig. 53.

area contained by a parabola $= \frac{2}{3}\,bh$, while the height of its centre of gravity above the neutral axis $= \frac{2}{5}h$. It is even probable that the curve bounding the stresses actually produced will take a still more curved form, on account of the shear stresses producing a distribution of strain, as already pointed out in reference to Fig. 50.

The actual strength of a rectangular beam as found by experiment is considerably greater than that found by theory, and this is probably due in part to the assumption that a plane section remains a plane surface after bending has occurred, and in part to the continuous support and resistance to lateral swelling or contraction afforded between layer and layer. In armoured concrete the latter effect will be increased by the use of stirrups, and is the basis of the results achieved by M. Considère's hooped concrete (see page 41). It is usual to meet these uncertain quantities by increasing the safe limiting stress, which may safely be raised to 500 lbs. per square inch, a figure which is commonly used; but it must not be forgotten that this value may only be used in the consideration of resistance to bending.

The safe stress upon the compressional side of the beam thus becomes $\frac{2}{3}\,bh \times 500$ lbs.

Resistance of Beams.—Before being able to calculate the strength of a beam the value of h must be found; for as the value of E in compression and tension is not the same, the neutral axis is now no longer fixed at the centre of gravity of section.

Assuming that $\frac{E_s}{E_c} = 10$, and that the limiting stress of concrete and steel are simultaneously reached, and taking these values as $c = 500$ lbs. per square inch, and $f_t = 16{,}000$ lbs. per square inch, then—

Maximum strain in compression : maximum strain in tension $= \frac{500}{E_c} : \frac{16{,}000}{E_s} = 1 : \frac{16{,}000}{500 \times 10} = 1 : 3.2.$

Then from similar triangles (see Fig. 61)—

$$h : d-h = 1 : 3.2.$$

$$\therefore \frac{h}{h+(d-h)} = \frac{1}{1+3.2}.$$

$$\therefore h = \frac{d}{4.2}.$$

$\therefore$ Safe resistance of concrete in compression $= \frac{2}{3}\,bh \times 500 = \frac{2}{3}\,\frac{bd}{4.2} \times 500.$

For equilibrium the reinforcement must have equal tensile resistance.

$\therefore$ At 16,000 lbs. per square inch, necessary area of

$$\text{reinforcement} = \frac{\frac{2}{3} \cdot \frac{bd}{4.2} \cdot 500}{16{,}000} = 0.005bd.$$

That is to say, in order that both concrete and steel may simultaneously reach their limiting stress the reinforcement should have a sectional area of .5 per cent. of that of the concrete.

If wrought iron be used for the reinforcement, with a safe tensile strength of 11,000 lbs. per square inch; taking $\frac{E_s}{E_c} = 10$, as before,

$$h : d-h = 1 : \frac{11{,}000}{500 \times 10} = 1 : 2.2$$

$$\therefore h = \frac{d}{3.2}$$

$$\text{and area of reinforcement} = \frac{\frac{2}{3} \cdot \frac{bd}{3.2} \cdot 500}{11{,}000} = .0095\ bd$$

$= .95$ per cent.

Thus if 1 per cent. or a larger proportion of reinforcement be used it matters little whether it consist of steel or wrought iron, and whichever can be obtained most cheaply may be employed.

It should be noticed that all concrete below the centre of the reinforcement has been left out of the calculation, for whatever thickness here exists the strength of the beam will not be affected if, as is usual, the resistance of the concrete in tension is neglected. Many formulæ assume that this extra thickness of concrete is a particular fraction of the depth of the beam. For a beam 12 feet deep, one-sixth of depth may be a very suitable thickness, but this factor when applied to a beam 24 inches deep will be excessive.

Only the concrete above the centre of the reinforcement will therefore be considered, while a certain percentage of metal will be taken as indicating a percentage of the concrete above the reinforcement.

It will be seen in Fig. 54 that only a small portion of the concrete is of use in resisting compression, and

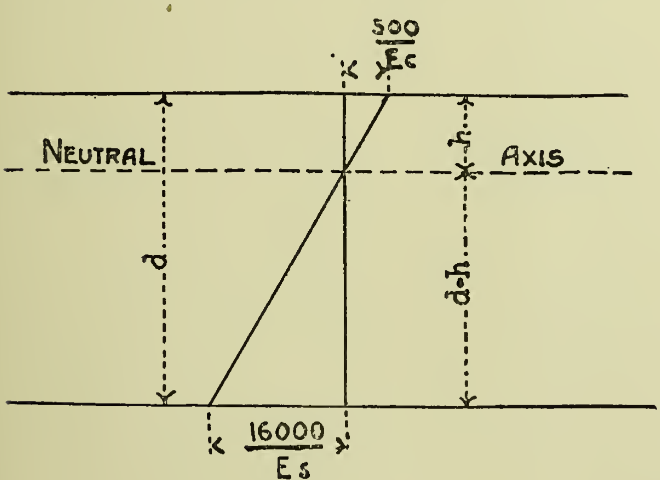


Fig. 54.

it does not follow, although the greatest use is made of the steel, that this proportion of $\frac{1}{2}$ per cent. will produce the cheapest and most convenient arrangement.

The effect of employing a reinforcement of 1 per cent. will now be investigated.

Let a = area of reinforcement.

Then resistance of concrete in compression = resistance of steel in tension.

$$\tfrac{2}{3}\,bhc = af_t;$$

$$\text{but } a = \frac{bd}{100}, \text{ and } c = 500.$$

$$\therefore \frac{2 \times 500}{3} bh = \frac{bd}{100} f_t.$$

$$\therefore f_t = \frac{100{,}000h}{3d}.$$

$$\therefore h : d-h = 1 : \frac{100{,}000h}{3d \times 500 \times 10} = 1 : \frac{20h}{3d}. \quad \text{(A)}$$

$$\therefore h = \frac{d}{1 + \frac{20h}{3d}} = .319d.$$

Substituting this value in (A)—

$$f_t = \frac{100{,}000 \times .319d}{3d} = 10{,}633 \text{ lbs. per square inch.}$$

The moment of resistance—

$$= \tfrac{2}{3}\,bhc\,(d - \tfrac{2}{5}h) \text{ (see Fig. 52).}$$
$$= \tfrac{2}{3}\,bhc \times .87d.$$
$$= 92.77\,bd^2.$$

To arrive at a general formula, let a = sectional area of reinforcement, and $r = \frac{E_s}{E_c}$.

$$\text{Then } \tfrac{2}{3}\,bhc = af_t.$$

$$\therefore f_t = \frac{2\,bhc}{3\,a}.$$

$$\therefore h : d-h = 1 : \frac{2bhc}{3a \times c \times r}.$$

$$\therefore h = \frac{d}{1 + \frac{2\,bh}{3\,ar}}.$$

$$\therefore h = \frac{3ar}{4b}\left(\sqrt{1 + \frac{8\,bd}{3\,ar}} - 1\right);$$

or if p = percentage of reinforcement, $a = \frac{bdp}{100}$, and substituting this value in the above formula,

$$h = \frac{3\,pdr}{400}\left(\sqrt{1 + \frac{800}{3pr}} - 1\right),$$

and the moment of resistance,

$$Mr = \tfrac{2}{3}\,bhc\,(d - \tfrac{2}{5}\,h).$$

The following table gives information found by the above formulæ for various percentages of reinforcement, which it should be noticed are percentages upon the area of concrete above the level of the centre of the reinforcement, the concrete below this being neglected.

$\frac{E_s}{E} = 10.$ Limiting stress on concrete = 500 lbs.

Percentage of Reinforcement upon Concrete above Level of Do. p	Distance of Neutral Axis from Surface at Compression Side of Beam. h	Tensile Stress on Reinforcement when $c=500$. f_t	Moment of Resistance.
0.50	0.238 d	16,000 lbs.	71.8 bd^2
0.75	0.284 ,,	12,622 ,,	83.9 ,,
1.00	0.319 ,,	10,633 ,,	92.8 ,,
1.25	0.349 ,,	9,307 ,,	100.1 ,,
1.50	0.375 ,,	8,333 ,,	106.2 ,,
2.00	0.418 ,,	6,966 ,,	116.0 ,,
2.50	0.453 ,,	6,040 ,,	123.6 ,,
3.00	0.482 ,,	5,356 ,,	129.7 ,,
3.50	0.508 ,,	4,838 ,,	134.9 ,,
4.00	0.531 ,,	4,425 ,,	139.4 ,,

In Fig. 55 are shown the sections of four beams with varying percentages of reinforcement, all being calculated to give the same moment of resistance of 360,000 inch-pounds. For the sake of comparison their widths have been kept constant. It will be seen that very little saving in depth is obtained by the use of a

higher percentage of reinforcement than 2 per cent. For simple beams of this description a reinforcement of 1 per cent. is very suitable, and has been largely adopted; while for tee beams, $\frac{1}{2}$ per cent. on area $B \times D$ may be adhered to (see Fig. 57).

SLABS.—A floor slab is usually supported by beams along its four edges. The slab thus supported may be considered as acting as a beam in two directions at right angles to one another. If the slab be square, the load will be evenly distributed among the four edges, and the maximum bending moment and shear will consequently be only half such as would occur were the slab supported on two edges only. Thus with a square slab $BM = \frac{wl^2}{16}$, or if the slab be continuous, and the reinforcement be transferred to the upper surface in passing over the supports, the BM at centre may be taken as $\frac{wl^2}{24}$, and over supports, say $\frac{wl^2}{20}$.

When a slab is twice as long as it is broad the supports at either end only very slightly reduce the bending moment at the centre, and the slab may then be considered as a simple beam supported along its two long sides.

For intermediate proportions the BM parallel to the short sides may be found by multiplying by $\frac{L^4}{L^4+B^4}$ that obtained when considering the slab as a simple beam of length B; where L = length of slab and B = breadth. The BM parallel to the long sides may be similarly found by multiplying by $\frac{B^4}{L^4+B^4}$ the BM obtained when considering the slab as a simple beam of length L.

Slabs are usually reinforced with rods at right angles to one another across length and breadth of slab. These reinforcements must be capable of meeting the BM as found with the aid of the above factors. The dimensions may be ascertained as set forth for beams, a strip of the slab 12 inches wide being taken for calculation. Suppose that a slab 8 feet × 12 feet is to support a load of 160 lbs. per square foot, which load includes the weight of the slab, and that the slab will be freely supported at its edges.

BM across short way of slab—

$$= \frac{wB^2}{8} \times \frac{L^4}{L^4+B^4}$$

$$= \frac{160 \times 8^2}{8} \times \frac{12^4}{12^4+8^4} \text{ foot-lbs.}$$

$$= 12826 \text{ inch-lbs.}$$

BM across long way of slab—

$$= \frac{wL^2}{8} \times \frac{B^4}{L^4+B^4}$$

$$= \frac{160 \times 12^2}{8} \times \frac{8^4}{12^4+8^4} \text{ foot-lbs.}$$

$$= 5701 \text{ inch-lbs.}$$

Assuming that a reinforcement of 1 per cent. is to be employed (see table above)—

$$92.8\, bd^2 = 12826, \text{ but } b = 12.$$

$$\therefore d^2 = \frac{12826}{92.8 \times 12}.$$

$$\therefore d = 3.4, \text{ or say } 3\tfrac{1}{2} \text{ inches}$$

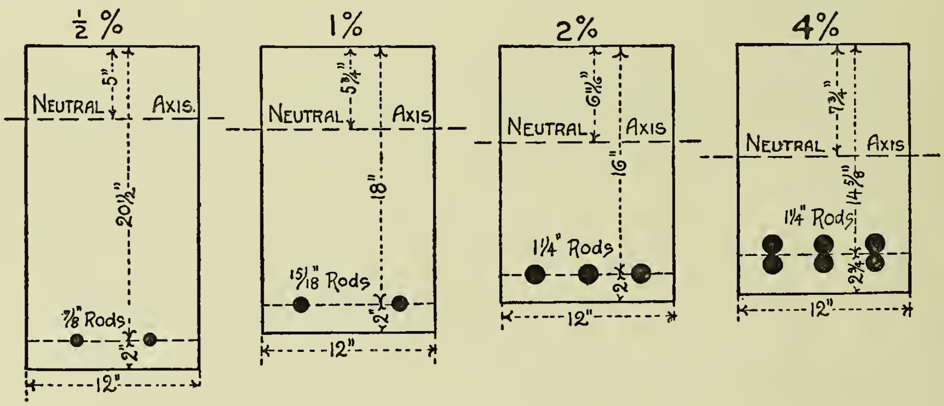


FIG. 55.

And area of reinforcement $= \frac{3\frac{1}{2} \times 12}{100} = .42$ square inch per foot of width, say 4 – $\frac{5}{8}$-inch rods to the foot,—that is, 3 inches apart.

Now, considering the reinforcement in the length of the slab—

$d = 3\frac{1}{8}$ inches (see Fig. 282), and representing the coefficient of bd^2 by k,

$$kbd^2 = 5701.$$

$$\therefore k \times 12 \times (3\tfrac{1}{8})^2 = 5701.$$

$$\therefore k = 48.6.$$

On turning to the table given above it is seen that something less than $\frac{1}{2}$ per cent. is required. $\frac{1}{4}$-inch diameter rods 4 inches apart may, however, be used, which is equivalent to .39 per cent.

The full depth of the slab will be $3\frac{1}{2}$ inches plus the covering to the reinforcement,—or, say, a total of $4\frac{1}{2}$ or 5 inches (see Fig. 56).

Calculations of this sort will not often be necessary, as uniformity in size and arrangement of rods is to be aimed at as far as possible.

In either slabs or beams it is preferable to use a number of rods of fairly small section in place of a few large ones, in order that their effect may be evenly distributed, and also that the metal may be removed as far as possible from the neutral axis.

TEE BEAMS.—Where floors are entirely moulded *in situ* the floor slab, together with the beam attached to it, form a beam of tee section, the portion of the slab on either side of the rib affording resistance to compression, while the rib itself chiefly acts in holding the tensile reinforcement. The form of the beam produced may be seen in Fig. 57.

As the slab is continuous on either side of the rib, the

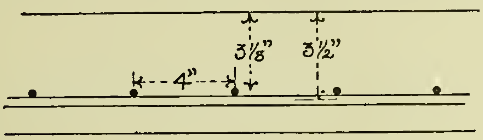


FIG. 56.

width that may be considered as forming part of the tee beam must be decided upon. In the case where a simple series of beams supported at their extremities is used the width of the flange of tee may be taken as extending to points centrally between beams; where, however, secondary beams supported on main beams are employed, the compressive stress induced in the horizontal member in carrying its load as a slab will act in the same direction as that induced in the flange of the main beam. Thus in the latter case the full width of slab cannot be considered as taking the compressive stress of the beam. It will be safe, however, in all cases to consider that the flange of the beam

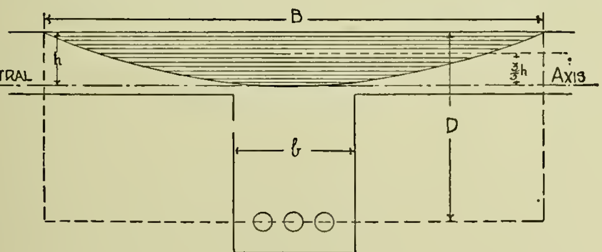


FIG. 57.

extends to a quarter of the span on either side of the rib.

The calculations for tee beams will be precisely the same as those for rectangular beams, provided that the neutral axis does not fall below the lower surface of the slab. Fig. 57 illustrates a case in which the neutral axis is above the lower surface of the slab. The formulæ given on page 37 may then be applied, substituting B (or half width of bay) for b, and total depth D for d; while p, the percentage of reinforcement, must be taken on area B × D as shown dotted. This dotted area, in fact, represents a beam of equal strength to that of the tee beam,—that is, if the resistance of concrete in tension be neglected; however, in the case of the tee beam the use of an ample supply of reinforcement passing through the depth of the beam is most necessary.

The formulæ become—

$$h=\frac{3ar}{4\mathrm{B}}\left(\sqrt{1+\frac{8\,\mathrm{BD}}{3ar}}-1\right).$$

$$h=\frac{3p\mathrm{D}r}{400}\left(\sqrt{1+\frac{800}{3pr}}-1\right).$$

$$\mathrm{M}r=\tfrac{2}{3}\,\mathrm{B}hc(\mathrm{D}-\tfrac{2}{5}h).$$

It will be noticed that the width of the rib does not enter into the calculations. It should, however, be proportioned to the depth of the rib, and should be sufficient to allow the concrete to be well packed round the reinforcement.

Fig. 58 shows a tee beam with its stress area, in which the neutral axis falls below the lower surface of the slab. The above formulæ are not strictly applicable to this case; but formulæ deduced on the same principles are too complicated to warrant their adoption.

COMPRESSIONAL REINFORCEMENT.—It is sometimes

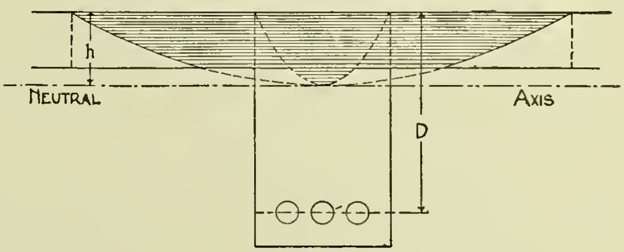


FIG. 58.

desirable to use a metal reinforcement in the compressional portion of a beam as well as in the tensional portion, in order to gain a reduction in depth, while some systems always adopt it. Its use, however, in this position is not economical.

The metal must be strained to the same extent as the surrounding concrete, and as the stress required to produced strain in steel equal to that in concrete $=\frac{\mathrm{E_s}}{\mathrm{E_c}}.c$, the stress upon the reinforcement will be ten times that upon the concrete. Thus if the surrounding concrete is stressed to 500 lbs. per square inch, the stress upon the steel will be $500\times10=5000$ lbs. per square inch; but as the steel must necessarily be embedded below the surface of the concrete, the actual stress will be less than this.

In Fig. 59 the compressional reinforcement is shown at depth g below the surface, and according to the theory of similar triangles the strain at this point will be $\frac{h-g}{h}\times$ strain at surface; consequently the stress in the reinforcement becomes $r.c\frac{h-g}{h}$, where $r=\frac{\mathrm{E_s}}{\mathrm{E_c}}$.

Let a_c = sectional area of compressional reinforcement, and a_t = sectional area of tensile reinforcement.

Total compressional stress = total tensile stress—

$$\therefore \frac{2}{3} bhc + a_c c . r . \frac{h-g}{h} = a_t fr.$$

$$\therefore f_t = \frac{2 bh^2 c + 3 a_c cr(h-g)}{3 a_t h}.$$

$$\text{Again, } h : d - h = 1 : \frac{f_t}{cr}$$

$$= 1 : \frac{2 bh^2 + 3 a_c cr (h-g)}{3 a_t hr}.$$

$$\therefore h = \frac{d}{1 + \frac{2 bh^2 + 3 ar (h-g)}{3 a_t hr}}.$$

$$\therefore h = \frac{3r}{4b} \left\{ \sqrt{\frac{8b}{3r}(a_t d + a_c g) + (a_t + a_c)^2} - (a_t + a_c) \right\}$$

Moment of resistance = moment of resistance of concrete + moment of resistance of compressional reinforcement.

$$\therefore \mathrm{M}r = \frac{2}{3} bhc \left(d - \frac{2}{5} h\right) + a_c cr \frac{h-g}{h}(d-g).$$

A compressional reinforcement is particularly useful where a tee beam passes over a support ; for here, where the stresses are reversed, the comparatively thin rib has to meet the compressional stress without the aid of the horizontal member which resisted compression at the centre of the span. This reinforcement is readily provided by simply carrying the members, which served as tensile reinforcement at the centre, straight along the lower side and over the supports. Further compressive resistance is provided at this point by the splaying out of the pillars immediately below the beam, as seen in Fig. 34. In using the formulæ just given it should not be forgotten that the use of compressional reinforcement adds to the strength of the concrete by bridging over weak points, as pointed out elsewhere ; thus the latter formulæ, as compared with those given on page 39, probably err on the side of safety.

Shear.—The necessity for the use of members to resist shear has already been discussed.

If the total vertical shear at any point in a beam's length = S, where depth of beam = d feet, the average horizontal shear at this point $= \frac{S}{d}$, while the maximum shear at neutral axis $= \frac{3}{2} \times \frac{S}{d}$. Vertical or inclined stirrups should be used, offering sufficient

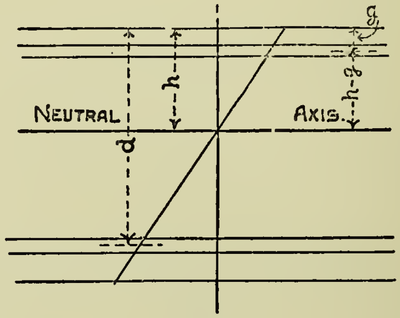


Fig. 59.

sectional area to resist this stress. The resistance of steel in shear may be taken as 11,000 lbs. per square inch.

All stirrups used in a beam will, for convenience, be of equal dimensions, being placed next together at the supports where the shear is greatest, and farther apart at the centre of the span. In the Hennebique system the tensile reinforcements which are sloped up over the supports are usually considered as meeting half the shear at the ends, while stirrups are arranged to resist the remaining half.

CHAPTER V

ARMOURED OR REINFORCED CONCRETE FOR VARIOUS USES

(*Contributed by P. R. Strong*)

Pillars.—As already seen, vertical reinforcement is employed in the construction of pillars, its use being to help to distribute the load past weak points in the concrete, and to give to the concrete more uniform properties, and at the same time to reduce the cross section of the concrete by assisting in carrying the load. The hooping of concrete has a further use.

As stated when considering beams, the reinforcement in compression must be strained to the same extent as the concrete which surrounds it, and the stress upon it will therefore be cr, where c = stress upon concrete and $r=\frac{E_s}{E_c}$.

The safe load for a rectangular pillar is thus $SL = bdc+acr=c\,(bd+ar)$, where b and d are the dimensions of the section of the pillar, and a = sectional area of reinforcement.

The above value may be allowed for pillars up to a length of about 15 b. Thus, taking a safe load of 400 lbs. per square inch, a pillar 12 feet long and 10 inches square with 2 square inches of vertical reinforcement will carry a safe load of $400\,(10^2+2\times 10)=48{,}000$ lbs.

Having proportioned a pillar by the above formulæ, the safety of long pillars against flexure is usually supposed to be calculated by Euler's formulæ, in which safe load $=E_c I\frac{\pi^2}{Sk}$, where E_c = modulus of elasticity for concrete, S = factor of safety; while $k=\frac{1}{2}$ for pillars with both ends fixed, 1 when both ends are hinged, and $\frac{1}{\sqrt{2}}$ when one end is fixed and the other hinged. The moment of inertia, I, for a reinforced section, may be taken as $\frac{bd^3}{12}+ary^2$, where y = distance of reinforcing bars from the central axis of section.

Euler's formula, however, is only accurate for very long pillars, and is not at all suitable for use in the case of concrete.

An adaptation of Rankine's formulæ would be more suitable—

$$SL=\frac{Ac}{1+k\frac{l^2}{r^2}}$$

where $A = bd+ar$

c = safe load per square inch on concrete = say, 400 lbs.

l = length in the common unit.

$$r^2=\frac{I}{A}=\frac{\frac{bd^3}{12}+ary^2}{bd+ar}.$$

The value of coefficient k may be taken as $\frac{1}{40{,}000}$.

According to this formula the safe load for a pillar 20 feet long, 10 by 10 inches with 2 square inches of vertical reinforcement, the centres of rods being 2 inches from outer surface or 3 inches from axis, is found as follows—

$$A=10\times 10+2\times 10=120 \text{ square inches.}$$

$$r^2=\frac{\frac{10^4}{12}+2\times 10\times 3^2}{10^2+2\times 10}=8.4.$$

$$\therefore\ SL=\frac{120\times 400}{1+\frac{1}{40{,}000}\cdot\frac{(20\times 12)^2}{8.4}}=40{,}975 \text{ lbs.}$$

Hooped Concrete.—All solid materials will resist an unlimited pressure so long as the part subjected to the load is prevented from expanding or escaping either laterally or vertically. Thus in considering the bearing resistance, or resistance to local compression, of steel, a considerably larger value was allowed than was done for ordinary compression; for in this case the metal was prevented from escaping laterally by the metal on either side. This result may be obtained with concrete by simply winding it round with steel wire, producing M. Considère's "Hooped Concrete." In this way an ultimate resistance on the concrete of over 10,000 lbs. per square inch may be obtained (see Fig. 60).

In order to more effectually confine the concrete and to prevent it from escaping laterally, vertical rods are also used, producing a network, the vertical rods transmitting the thrust caused by the swelling of the concrete to the helical binding, while in long pillars their use is further necessary in the resistance to flexure.

According to M. Considère, the resistance of hooped concrete = the resistance of the vertical rods and the concrete at their elastic limits + 2.4 × the resistance that would be offered by the metal in the hooping if it were used as vertical reinforcement in place of spiral binding. He also states that the hooping should be

spaced with a pitch of $\frac{1}{7}$ to $\frac{1}{10}$ of diameter of the winding.

Only concrete within the hooping may be considered as resisting compression; that outside the hooping acting merely as a protection. Besides the greatly increased resistance offered by this method of construction, it has the further advantage that any signs of

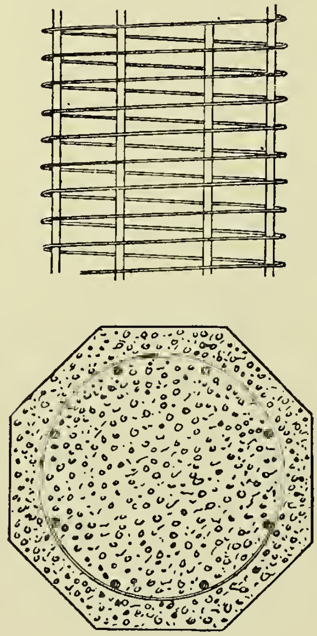


Fig. 60.

distress in the material are at once made evident by the breaking away of the outer protecting skin of concrete, which takes place long before the ultimate resistance is reached.

The wire ties in the pillars shown in Figs. 36, 68, etc., besides holding the reinforcement in position while the concrete is being filled in, act to some extent as do the hoopings mentioned above, while the nearer they are

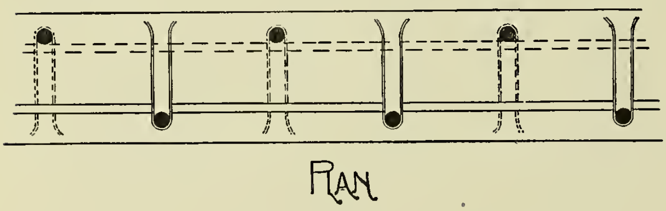


Fig. 61.

placed together the greater resistance will the resultant material have.

Walls.—The thickness of a wall, together with the extent of its reinforcement, must largely be a matter of practical consideration, for the thrusts that it may be called upon to meet as a general rule cannot be even approximately arrived at.

Fig. 61 shows the method of reinforcing a wall according to the Hennebique system, the wall being constructed as a slab capable of resisting thrust from either side.

Foundations.—Concrete always finds an important place in foundation work, and the nature of armoured

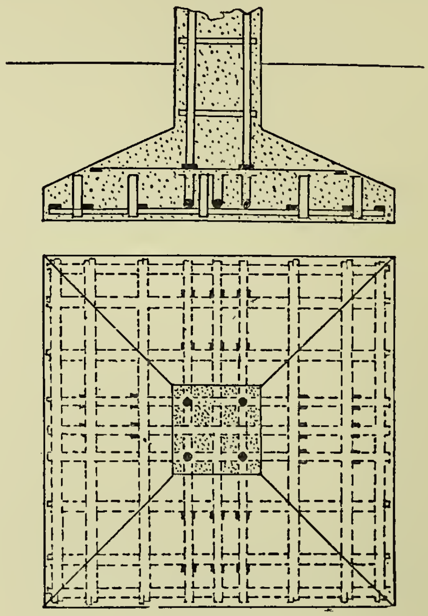


Fig. 62.

concrete makes it particularly suitable for use in this position, while the moulds, which usually form a con-

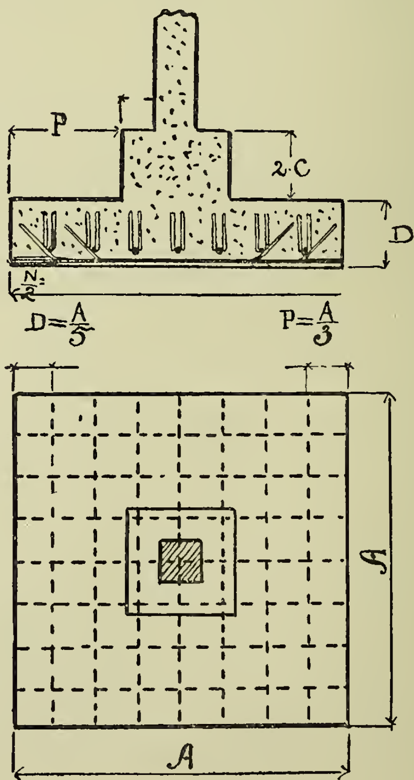


Fig. 63.

siderable portion of the cost of armoured concrete, are here reduced to a minimum.

Armoured concrete may be economically used for all

the methods of forming foundations mentioned in reference to steel frame buildings in Chapter XVI. Part II. Volume IV., while there is greater certainty of the thorough protection of steelwork than in the case of the grillage of steel beams.

Fig. 62 shows a common form of pillar foundation (Hennebique system), being very similar to the grillage brought by the pillar reinforcing rods. Stirrups are used here, as may be seen in the illustration, while Fig. 63 shows the use of the Kahn bar with its diagonally sloping wings.

Where it is necessary to construct a concrete raft over the whole site, armoured concrete undoubtedly forms the most practical and economical method of doing

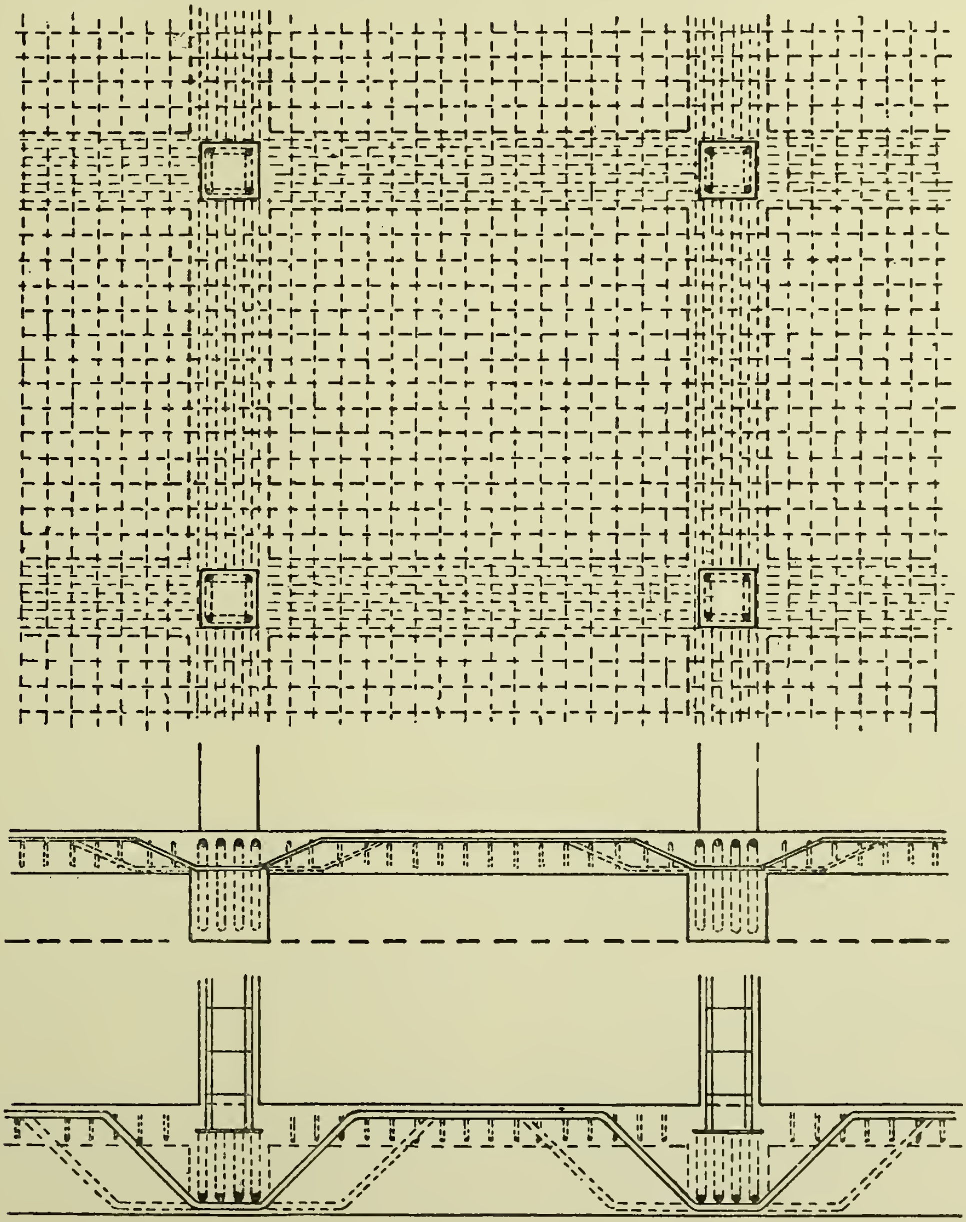


Fig. 64.

foundation shown in Fig. 184, Volume IV.; and as in that case the size of steel joists was arrived at by considering them as cantilevers, so here the necessary thickness of concrete and size of rods are calculated by considering the portions on either side of the central load as cantilevers, with an evenly distributed load acting upwards produced by the reaction of the earth. A plate is embedded in the footing to better distribute the load

this. Fig. 64 shows plan and sections of a portion of such a raft, which may be regarded as a similar construction to that of floors, but in a reversed position. At the centres of spans between supports the tensile stresses occur at the upper side of the beams and slabs, and the reinforcement is consequently placed in this position, while under the pillars the reinforcement is placed near the bottom surface.

Piles.—Where the use of piles is necessary, those formed of concrete are highly to be recommended for a structure which is intended to be permanent, as they are not only practically proof against damp, but they form one with the structure above.

Fig. 65 gives a section of the Coignet pile, in which a spiral rod about $\frac{1}{4}$ inch in diameter and having a pitch of 3 or 4 inches encircles the longitudinal rods. To prevent unwinding and to add to the rigidity of the

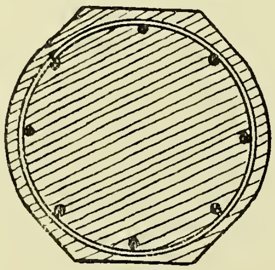


Fig. 65.

framework, another spiral wire of very long pitch runs in the contrary direction to the first. The two flat surfaces shown in the section are intended for guiding purposes during driving operations. With the exception of the increased pitch of the winding, this construction is very similar to the hooped pillars considered with reference to Fig. 60. Square piles are also made on this system.

Fig. 66 shows the reinforcement of a hollow pile on the Hennebique system before the concrete has been filled in.

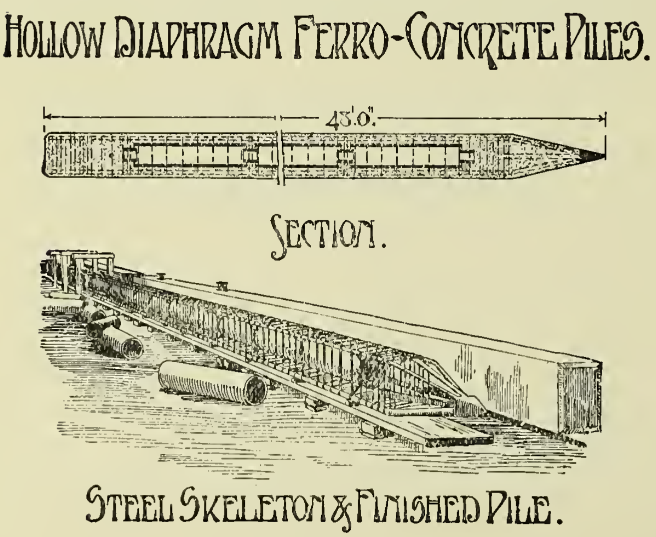


Fig. 66.

Fig. 67 shows the construction of a pile on the Williams system, it being reinforced with a rolled steel joist, the web of which is cut away and the flanges bent in to form the point of the pile. Around the joist, at intervals of about 12 inches, rings of $\frac{3}{16}$-inch wire are placed, while the flat steel bars *a* are added when increased bending resistance is necessary in the direction at right angles to the web of the joist.

Concrete piles are pitched and driven as are ordinary timber piles, and the fact that this is possible forms abundant proof of the resistance of the material to shock. In driving the piles the head is protected by a steel cap containing a pad of sawdust, the upper side of which is fitted with a hard wood dolly about 3 feet long; this arrangement being used to bring the blow evenly upon the head of the pile and to deaden the shock.

When the pile has been driven the concrete about its head is cut away, leaving the reinforcement projecting. The latter is then embedded in the concrete superstructure, or the pile may be lengthened in the same manner as it was originally constructed. Fig. 68 shows a pile foundation to a pillar, in which the intimate

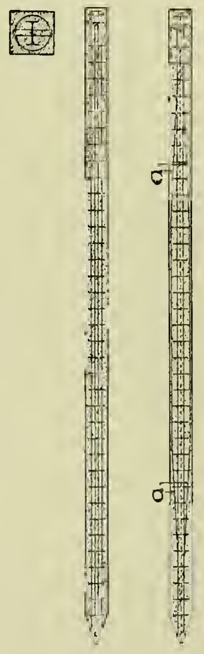


Fig. 67.

connection between the pile and the spread foundation may be seen.

Another variety of pile, the "Simplex Concrete Pile," is shown in Fig. 69. In constructing this an iron tube is first driven into the ground to the required depth, being closed in at its lower end by an "Alligator Point," the driving being done by the ordinary pile driver. After this form has been driven it is filled with concrete to a height of about 3 feet above its bottom end. The form is then pulled up 2 feet, the jaws of the alligator point opening wide and allowing the concrete to pass through. The concrete is then rammed with a 600 lbs. drop hammer. The process is thus repeated until the pile is complete. The first diagram in Fig. 69 shows the process of withdrawing the metal form and ramming the concrete; the second shows the pile completed, and also the bucket used for discharging the concrete; while the third diagram shows a wharf pile, the upper portion being reinforced to meet lateral

pressure and shocks, the reinforcement in the form of a cage being lowered into the tube while it is being filled with concrete, and the tube being left in position for so much of its length as would be surrounded by water or friable earth.

The advantages of this system are that the piles are made on the spot to the exact length that is found necessary; that the sides are rough, and offer great frictional resistance between pile and earth, while the shape of the pile is also conducive to great carrying power.

Retaining Walls.—These form a particularly striking instance of the economy that is attainable with this form of construction. In the case of masonry,

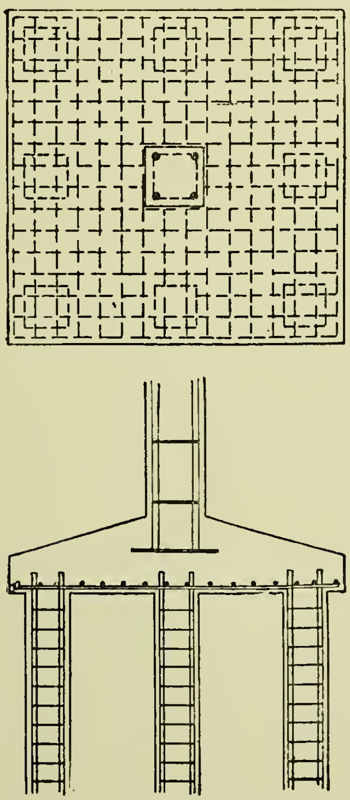


Fig. 68.

very heavy massive walls are necessary to resist the overturning effect of the earth pressure, and at the same time to avoid the presence of tensile stresses. In armoured concrete, ledges may be formed at the back of the wall, and the earth vertically above these, which they support, adds to the weight of the wall, and greatly assist its resistance to overturning; while, at the same time, a toe can be conveniently formed at the face of the wall which will bring the pressure more evenly upon the foundation-bed. Fig. 70 shows such a retaining wall reinforced with Kahn trussed bars. It will be observed that the face of the wall acts in the same manner as a floor slab, the reinforcing bars being placed nearer together at the foot where the pressure is greatest. The top half of the wall forms a simple cantilever of tee section, the "counter forts" or webs being in tension and the wall slab in compression.

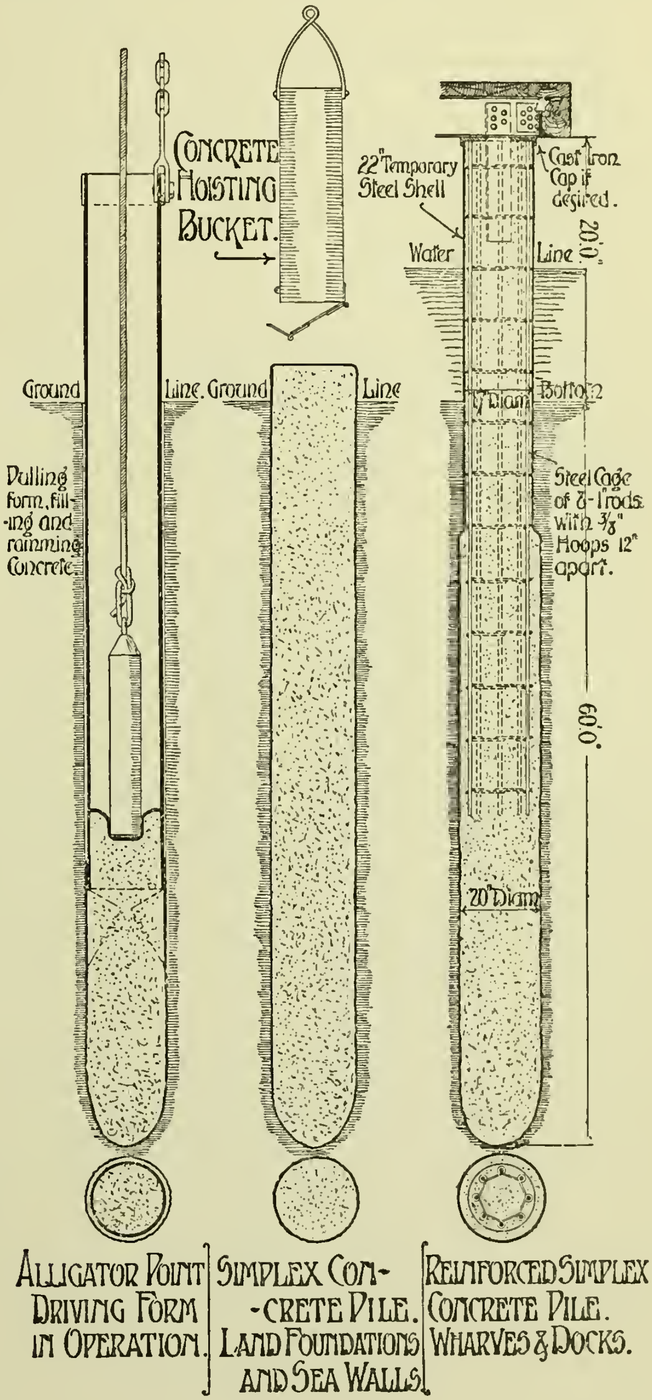


Fig. 69.

Fig. 71 shows another example of this form of construction, in conjunction with concrete piles, for a quay wall on the Hennebique system. The lightness of the construction is very noticeable.

Arches.—Arches of armoured concrete have the

considerable advantage over those of masonry that the line of pressure need not necessarily pass through

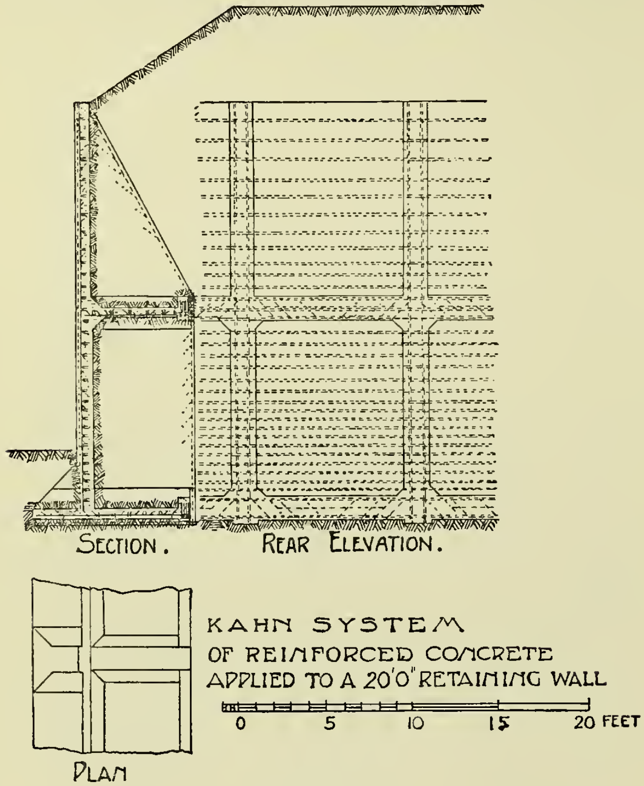


FIG. 70.

the middle third of the depth of the arch ring, for the tensile stresses, set up by the departure from this

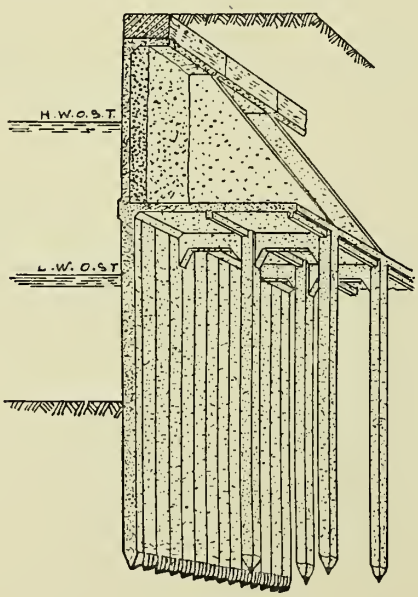


FIG. 71.

rule, are taken by the reinforcements, and the depth of the ring may consequently be much reduced.

A double reinforcement, such as is shown in Fig. 72, is generally adopted, but if the only continuous reinforcements be placed near the lower surface, further reinforcements should be used at the upper side of the arch, enbedded in the abutments, and extending inwards for not less than a quarter of the span.

The exact position at which tensile stresses may be induced cannot be definitely ascertained, and depends upon shape of arch and distribution of loading. Thus the line of pressure may be disposed as shown by the thick dotted line in Fig. 73, producing tension at the points marked T. It is therefore advisable to use a

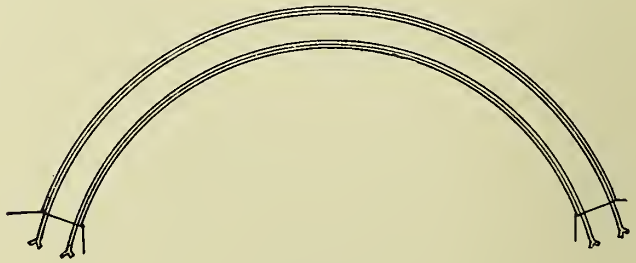


FIG. 72.

double reinforcement throughout. Stirrups or similar members are also advisable in order to bind the layers of concrete together.

In the case of a three-hinged arch—that is, one with hinges at springings and crown—the line of pressure must pass through these three points, and can be located fairly accurately. Also, the arch is independent of the effects of temperature and of the uneven settlement of the abutments. It will seldom happen in the case of an arch without hinges that the line of pressure will pass through the axis of the arch at these three points, and the disposition of stress and

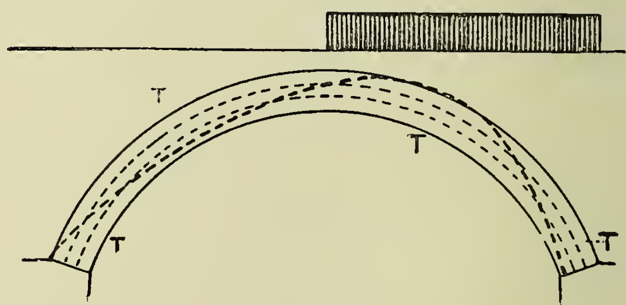


FIG. 73.

the effect of temperature or unequal settlement must be uncertain.

It will probably not be far from the truth if it be assumed that the line of pressure passes through the axis of the arch at its crown, and that the horizontal thrust for an evenly distributed load $= H = \frac{wl^2}{8R}$,

where w = total load per foot-run (dead + live).
l = span of arch in feet.
R = rise of arch in feet.

The depth of ring may then be proportioned to resist this load by the pillar formulæ given at the commence-

ment of this Chapter. The strength of the arch at any other point may be calculated as follows:—

T = thrust at point under consideration. (This may be split up into two thrusts parallel and normal to the axis of the arch. The latter will produce shear only, and may be neglected.)

Let P = component of T parallel to axis,

and e = the eccentricity, or distance between pressure curve and axis of arch.

The effect of P will be to produce a total stress P distributed throughout the section + the stresses produced by bending moment P . e.

Let c_1 equal the compressive stress produced by the direct compression of P.

$$\text{Then } c_1 = \frac{P}{bd + 10(a_c + a_r)}.$$

Then, if $c = 400$ lbs. per square inch = maximum allowable stress on concrete, the maximum stress per inch available to resist the BM $= c_2 = c - c_1$.

Now, applying the beam formulæ (near the end of last Chapter), and having found the value of h from the formula there given—

$$Mr = \tfrac{2}{3}bhc_2(d - \tfrac{2}{5}h) + a_c c_2 r \frac{h-g}{h}(d-g).$$

The latter value will check the ring's resistance to bending, which must not be less than Pe.

The stress in the tensile reinforcement

$$= f_t = \frac{2bh^2c + 3a_c cr(h-g)}{3a_t h} - rc_1.$$

The greatest bending moment will, as a rule, be in the proximity of $\frac{1}{4}$ span, where the thrust may be taken as roughly—

$$\frac{w_2 l^2}{16R}(2w_1 + w_2) \text{ sec. } a.$$

$$\text{and BM} = \frac{w_2 l^2}{64},$$

where w_1 = dead load per foot.

w_2 = live load per foot.

l = length of span in feet.

R = rise of span in feet.

a = angle between axis of arch at point under consideration, and the horizontal.

By the use of reinforcements, bending moments may likewise be allowed in the abutments, producing proportions which at first sight might appear to be much too slight to resist the thrust of the arch. This is seen in Fig. 74, in which an evenly distributed load

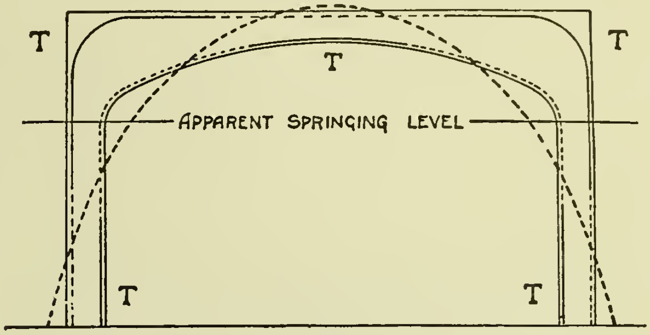


Fig. 74.

on the arch will produce tensile stresses in the reinforcements T shown in full lines. The arch may, in fact, be considered as springing from ground level, instead of from the apparent springing level, while

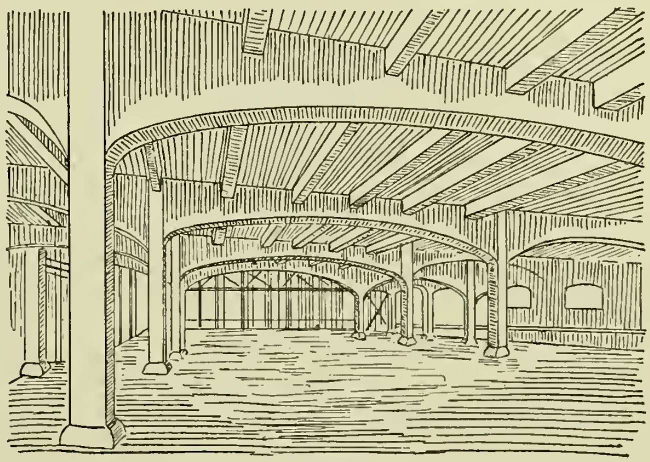


Fig. 75.

the line of pressure becomes somewhat as shown in a heavy dotted line.

Fig. 75 shows the pleasing effect and lightness of this construction when used for floors (Hennebique system), the span being 46 feet.

CHAPTER VI

THE GEOMETRY OF MASONRY

(*Contributed by* *Walter Hooker*)

In considering the application of the principles of masonry to practical use the object has been to eliminate from the examples given, as far as possible, the introduction of calculations of an abstruse nature. By this means it is hoped to bring within the understanding of both the mason and the student such principles as are needful in meeting with and solving all ordinary problems that may occur in actual practice.

As a considerable amount of skill both in plane and solid geometry, and also of projection, is required to enable the mason to determine the shapes of the stones of the various features of a building, this chapter is devoted to the subjects above named; and the several diagrams and their explanations which it contains will be found sufficient to clearly and concisely demonstrate the more useful problems that may be required in ordinary building work. One or more problems are inserted that more strictly apply to engineering, but their utility will perhaps be appreciated as showing the principles of stereotomy outside of the architect's legitimate sphere.

Each problem is illustrated by outline diagrams, and in the more advanced stages by perspective views or by isometric drawings.

It is presumed that the reader has already a fair acquaintance with the rudiments of practical geometry, algebra, and the elements of Euclid. It would be impossible otherwise within the limits of this work to give sufficiently detailed instruction to enable the student to benefit materially by its introduction.

Proportionals

Problem.—To divide a line in extreme and mean ratio.

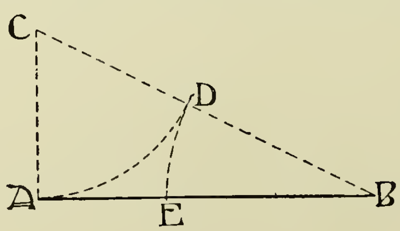


Fig. 76.

Let AB (Fig. 76) be the line. On A erect the perpendicular AC = ½ AB. Join CB. With C as centre and radius CA draw an arc cutting CB in D. With centre B and radius BD draw an arc cutting AB in E. AB is then divided in extreme and mean ratio at E.

That is, AE : EB : : EB : AB.

Problem.—To find a mean proportional between two given lines.

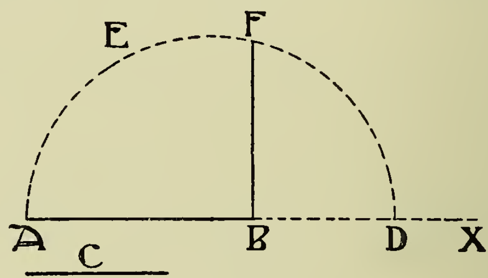


Fig. 77.

Let AB be the greater and C the lesser line (Fig. 77). Prolong AB indefinitely to X, and cut off BD = C. With AD as diameter draw a semicircle AED. Draw BF at right angles to AD to meet the semicircle in F. Then FB is a mean between AB and BD, which is = C.

That is, AB : BF : : BF : BD or C.

Problem.—To find a fourth proportional to three given lines

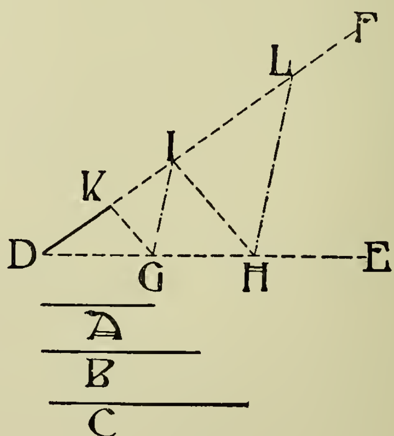


Fig. 78.

Let A, B, and C be the three given lines (Fig. 78). At any convenient angle with one another, say 35 or 40 degrees, draw DE and DF. From DE cut off

DG = A and DH = C. From DF cut off DI = B. Join IH, and draw GK parallel to IH, cutting DF in K.

KD is a fourth proportion to the lines A, B, C. That is, DH : DI : : DG :·DD, or in other words, C : B : : A : KD.

The above problem produces a proportional less than the given lines.

To produce a greater proportional, join GI and draw a line HL parallel to GI cutting the line DF in L. Then A : B : : C : DL, because DG : DI : : DH : DL.

Circles and Curves

Problem.—To set out the cusping in a circular window, say a trefoil cusp.

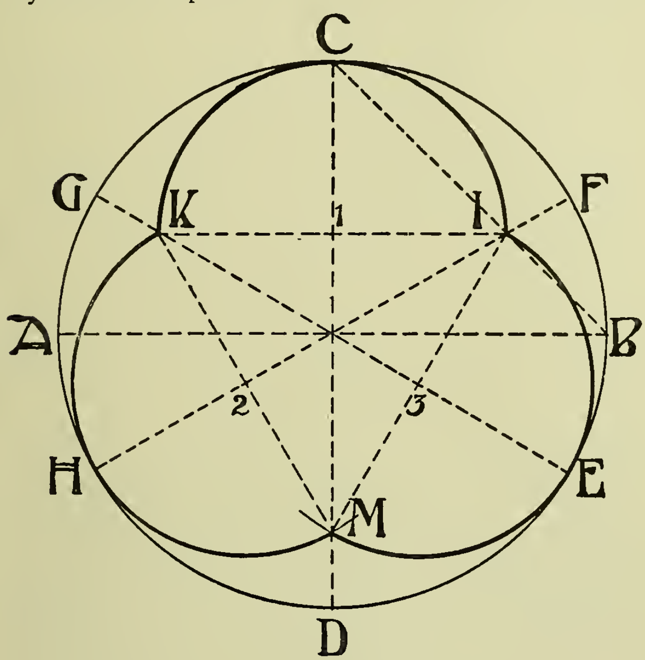


Fig. 79.

Let ACBD (Fig. 79) be a circle with diameters AB, CD at right angles to each other.

From D divide the circumference into 6 equal parts in E, F, C, G, H, and D. Join FH, EG. Join CB cutting FH in I. Through I draw a line IK parallel to AB cutting GE in K. IK is the diameter of one semicircle of the trefoil.

With I as centre and IK as radius, describe an arc cutting DC in M. Join IM and KM. Then the points marked 1, 2, and 3 will be the centres for the arcs of the trefoil, with radii 1 C, 2 H, and 3 E respectively.

Note.—Any number of cusps can be set out in the circle by dividing the circumference into twice the number of parts that there are to be cusps.

Problem.—Given any portion of the circumference of a circle, to find a point that will be within the circumference if produced. It is presumed that the portion of the circumference is too large to use the centre.

Let AB (Fig. 80) be the given portion of the circumference.

Take any convenient point C in this circumference, and join AC, CB, and AB. From B draw BD = AC,

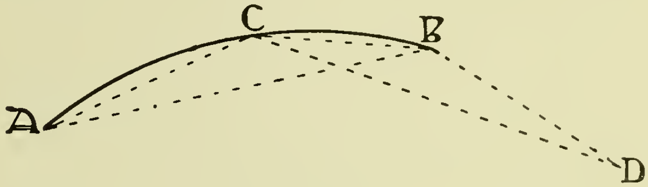


Fig. 80.

making the angle CBD = to the angle BCA. Then D is the point in the circumference required. As a check, join CD, which should be equal to AB.

Alternatively, instead of making the angle CBD = to the angle BCA by the use of an angle-measuring instrument, from the centre B, and with radius = AC, strike an arc. Similarly from C with radius = AB, strike another arc. These arcs will intersect at D.

Problem.—To find the length of the semi-circumference of a circle.

Note.—The ratio of diameter to circumference is denoted by the Greek letter π in all trigonometrical treatises, *i.e.* Diameter : circumference : : 1 : 3·14159, etc.

The geometrical method of determining the length of the circumference of a circle (shown in Fig. 81) will be found to give results which are quite accurate enough for practical purposes.

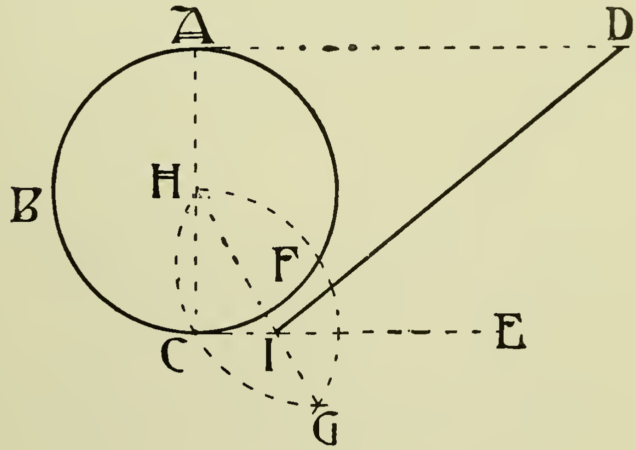


Fig. 81.

Describe any circle as ABC, and draw a diameter AC. From A draw AD at right angles to AC and equal in length to $1\frac{1}{2}$ times the diameter. From C draw CE parallel to AD.

With C as centre and with a radius = $\frac{1}{2}$ the diameter (that is = to CH) draw an arc cutting the circumference in F, and with F as centre and radius CH draw an arc meeting the first arc at G. Join GH, cutting CE at I. Join ID. Then ID is very approximately equal to the length of the semi-circumference.

The Projection of Solids.

In this section a few of the more useful projections only are given, it being presumed that the reader is already acquainted with the elementary principles of the subject.

The following projections will prove useful, as leading up to an understanding of the system employed in drawing a solid body in any position and projecting its surfaces horizontally and vertically, or at any angle or on to any plane as may be required. In the setting out of cylindrical or other curved surfaces a knowledge of this important section is most essential, and a careful study of the methods employed will greatly assist the student in grasping the system of projecting the shapes of regular or irregular stones forming the component parts of Vaults, Domes, etc.

Note.—In all the following problems the line forming the junction of the vertical and horizontal planes is called the *Line of Intersection*, and is abridged in the description to "L. of I."

Problem—To project the elevation of a solid triangular prism one face of which forms an angle of 30 degrees with the vertical plane. Vertical height $= e_1 f_1$.

Let *abcd* (Fig. 82) be the plan of the prism, at an angle of 30 degrees from the L. of I., and $e_1 f_1$ the height above the horizontal plane, while *eg* is the plan of the apex line.

Through *e*, *b*, *c*, *g*, and *d* project lines to the line of intersection, those from *e* and *g* being prolonged to the proposed height of the prism at f_1 and g_2 respectively. Make $g_1 g_2 = e_1 f_1$, and join $f_1 g_2$. Join $f_1 b_1$, $g_2 c_1$, and $g_2 d_1$. The figure $b_1 f_1 g_2 d_1$ will be the required elevation.

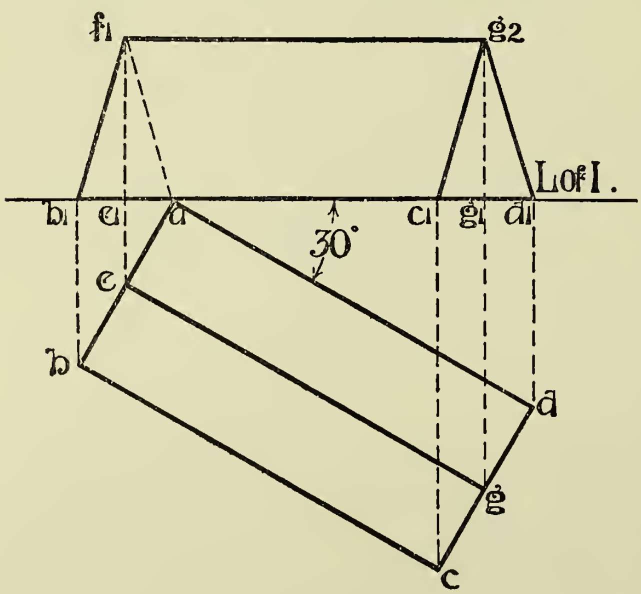


Fig. 82

The dotted line connecting $f_1 a$ will be the remaining arris, in this case not visible.

Problem.—To project a pyramid having a square base, one of its sides being at an angle of 30 degrees with the L. of I. Height $e_1 f$ (see Fig. 83).

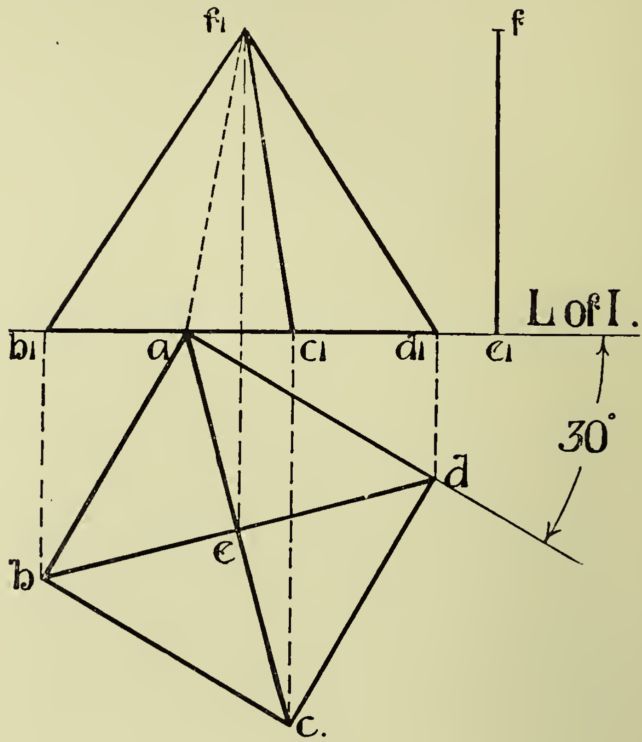


Fig. 83.

Let *abcd* be the plan, with *e* as apex.

Project lines of construction from points *b*, *c*, and *d* to the L. of I.; and from *e* to a point f_1 above the L. of I., making the height equal to the given height $e_1 f$.

Join f_1 to b_1, c_1, and d_1, thus completing the elevation of the required pyramid. A dotted line connecting f_1 and *a* will give the position of the remaining edge.

Problem.—To project a right cylinder having a horizontal axis at an angle of 30 degrees from the L. of I., and at a given distance above the horizontal plane.

In this case the plan will form a rectangle, as *abcd* (Fig. 84), 30 degrees from the L. of I.

Let *abcd* be the plan of the cylinder, placed at an angle of 30 degrees with the L. of I. Bisect *bc* and *ad* in *e* and *f*, and join *ef*. Then *ef* will be the plan of the axis of the cylinder.

Draw a line *gh* parallel to L. of I., and at the required height above it. Through *b*, *e*, *c*, *d*, *f*, and *a* project lines at right angles to the L. of I., intersecting *gh* in b_1, e_1, c_1, d_1, f_1, and a_1 respectively. Make $e_1 j$ and $f_1 k$ each equal to *bc*. Join *jk*. Bisect je_1 and kf_1 in *l* and *m*, and join these points. Produce *lm* both ways, meeting the vertical lines bb_1, cc_2, and dd_1 in b_2, c_2, and d_2 respectively. Make an ellipse $jc_2 e_1 b_2$ with je_1 as major axis, and $b_2 c_2$ as minor axis; and a semi-ellipse $kd_2 f_1$ (the other half, not visible, is shown dotted), thus completing the elevation of the cylinder.

Problem.—To find the plan of a cone whose axis is at

30 degrees from the horizontal and parallel with the vertical plane.

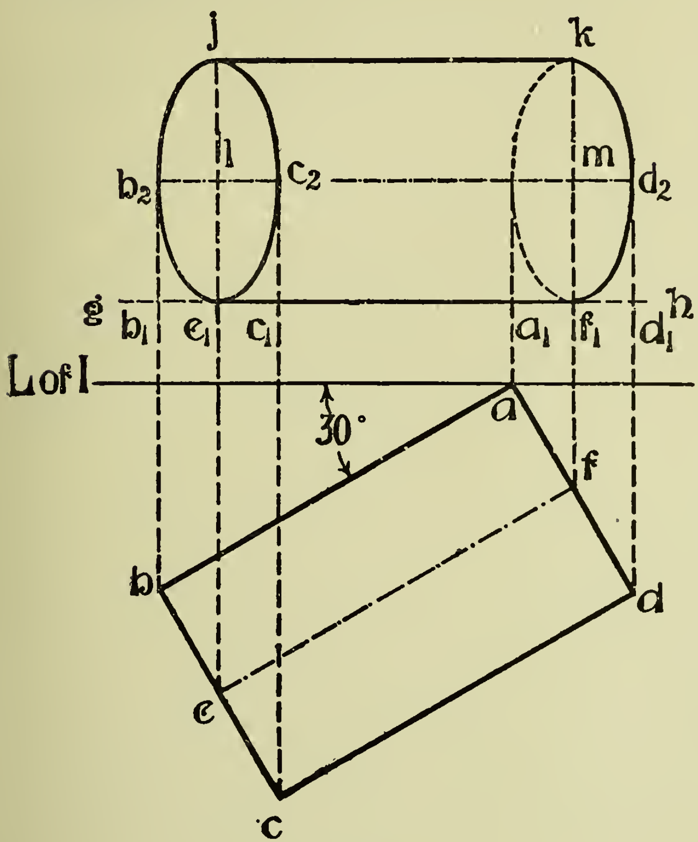


FIG. 84.

Let *abc* (Fig. 85) be the elevation of the cone, the axis *ad* forming an angle of 30 degrees with the line of

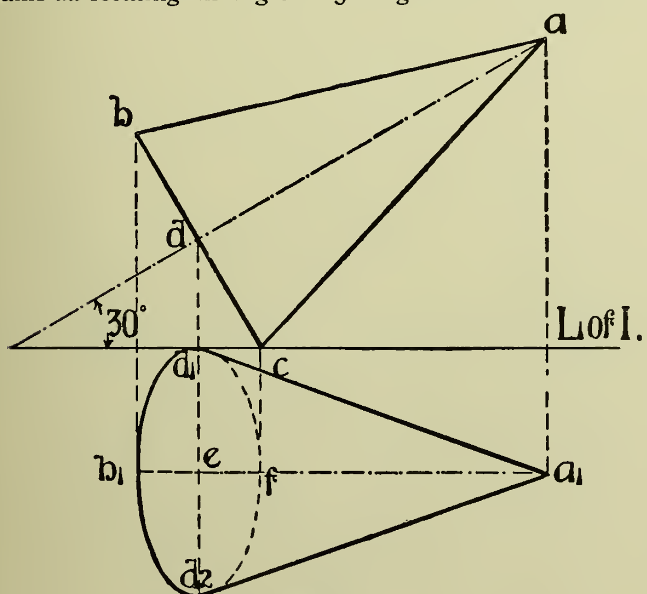


FIG. 85.

intersection. (The elevation of the cone in this instance forms an isosceles triangle.)

Project *a*, *b*, *d*, and *c* on and beyond the L. of I. to the horizontal plane, making $d_1d_2 = bc$. Bisect d_1d_2 in *e*, and draw b_1ea_1 parallel to the L. of I. Make $ef \times b_1e$; and with d_1d_2 as major axis, and b_1f as minor axis, construct the semi-ellipse $d_1fd_2b_1$. Draw a_1d_1 and a_1d_2 tangentially to the ellipse, thus completing the plan. The hidden portion of the circular base of the cone is shown dotted.

It is as well to remember the following axioms :—

The plan of a circle lying parallel to the horizontal will be a circle ; its elevation will be a straight line. If inclined to the horizontal its plan will be an ellipse.

If vertical, it will be a straight line on plan.

A cylinder, if its axis is parallel with the horizontal, will always be a rectangle on plan ; its elevation will be a rectangle if it be parallel with the vertical ; if at an angle, the ends will form ellipses.

A pyramid standing on its base will be a right-lined figure on plan and a pyramid in elevation.

A cone with base parallel to the horizontal will be a circle on plan, in elevation a triangle.

A sphere is a circle from all points of view.

INTERPENETRATION OF SOLIDS.

By interpenetration is meant the intersection of two bodies of similar or different form, resulting in a regular or irregular figure, as the case may be.

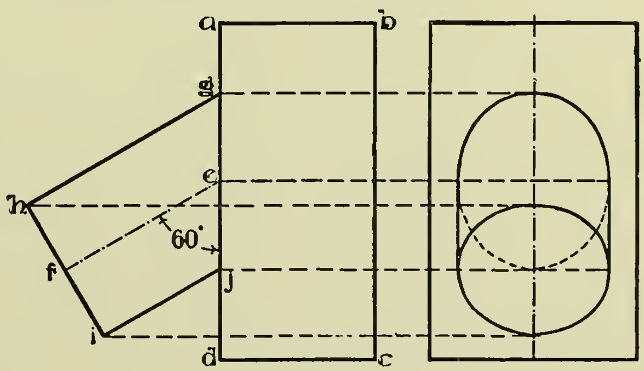


FIG. 86.

Take a simple case, namely, a cylinder penetrating a rectangular prism at an angle of 60 degrees.

Let *abcd* (Fig. 86) be the side elevation of a prism ; *ef* the axis of a right cylinder, and *ghij* the outline of the same.

It will be seen that the line of intersection *gj* is on a plane oblique to the axis of the cylinder *ef*; and *gj* will therefore be of greater length than *hi*, the diameter. Thus at the line of junction of the two bodies the contact line will be an ellipse, with major axis *gj* and minor axis $= hi$.

This is a simple form of interpenetration, and one frequently met with in masonry work.

Problem.—To determine the interpenetration of a cone and a cylinder.

Let *abc* (Fig. 87) be the side elevation of a cone, and *defg* a cylinder with its axis at right angles to that of the cone.

the cylinder in the same manner, as at RB_1SA_1; that portion shown by RA_1S being dotted. as not visible.

Draw in the outline of the prism.

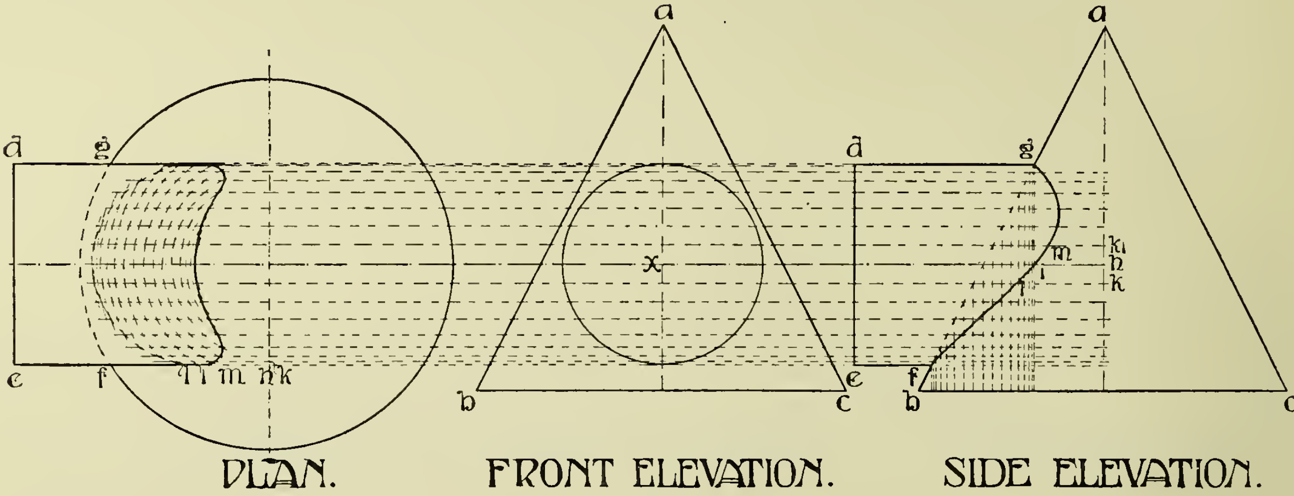


Fig. 87.

In this case the two bodies in question have curved surfaces. In front elevation the face of the cylinder shows as a circle. To find the curves of interpenetration in plan and side elevation, divide the semi-circumference of the circle on side of *x* into any convenient number of equal parts, say 16, and draw lines through the points thus determined at right angles to the axis of the cone, prolonging them to the plan and side elevation. Where these lines cut the slant side of the cone, project vertical lines to the base; and with the axis as centre and the points marked off by these lines in the base as the extremities of the radii draw concentric arcs on plan from the centre of the plan of the cone, cutting the lines previously drawn. Through the points of contact draw a curve; which will be the curve of interpenetration on plan. The curve of contact on the side elevation is found in the following manner: Make *hi*, *kl*, and k_1m on side elevation equal to *hi*, *kl*, and *km* on plan respectively. A curve drawn through *l*, *i*, and *m*, and points similarly found, on the horizontal dotted lines of Fig. 87, will give the curve of penetration on side elevation.

Problem.—On the interpenetration of a horizontal cylinder with a vertical prism.

Let ABDC (Fig. 88) be the plan of a cylinder with its axis forming an angle of 18 degrees with the L. of I.; and EFGH the plan of a vertical prism penetrated by the cylinder.

Project lines of construction from A, B, C, and D of the cylinder, and from the ends of the axis as shown by NO, above the L. of I. Project similar lines from the points E, F, G, and H of the prism. Let the cylinder be above the L. of I. Make O_1P and O_1Q equal to OD and OC on plan. The lines PQ and D_1C_1 will form the axes of an ellipse, which can be drawn by any of the usual methods. Proceed with the other end of

To find the curves formed by the contact of the two bodies.

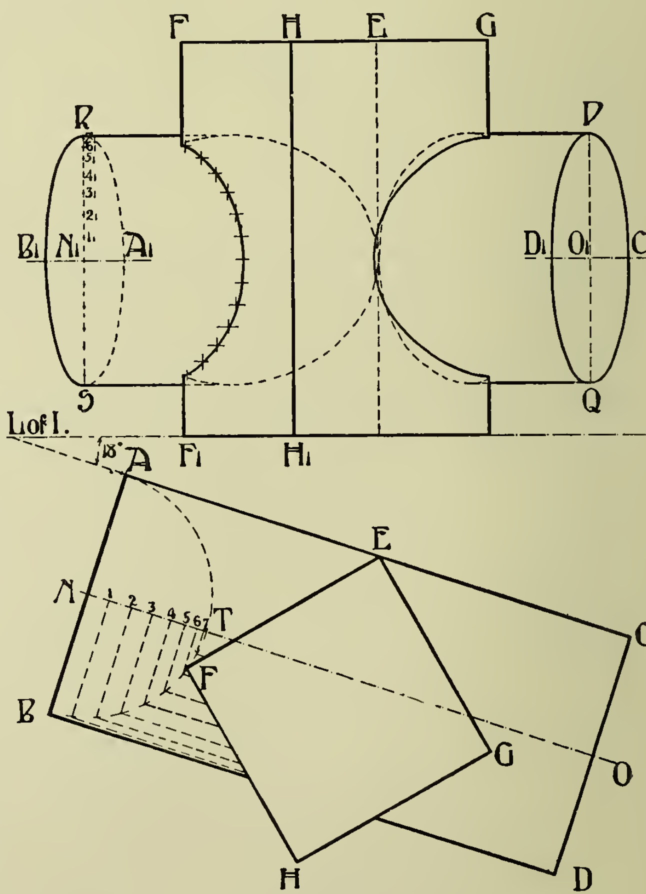


Fig. 88.

With N as centre and NA as radius describe a semicircle, and divide the semi-circumference into any

convenient number of equal parts. In this case a quadrant only is shown, divided into eight parts.

Project these points, by lines parallel to the axis of the cylinder, on to the side FH of the prism. From the points of contact thus found project vertical lines at a convenient distance above the L. of I., as shown.

From the divisions of the quadrant draw lines parallel to the diameter BA, cutting NT in 1, 2, 3, 4, etc., and from N_1R in the elevation cut off parts N_11_1, N_12_1, N_13_1, etc., equal to N1, N2, N3, etc., on the plan, and through 1_1, 2_1, 3_1, 4_1, etc., draw lines parallel to B_1C_1 cutting the lines projected from the intersections of the side of the prism FH. The crossings of these two sets of lines mark points on the curve of penetration, and through them the required curve is drawn.

etc. A curve drawn through these points a_1, b_1, c_1, etc., gives the plan of the line of penetration.

The curve shown on the left-hand side of Fig. 89 is that of the plan of the line of intersection of a cylinder cutting another cylinder obliquely, and is similarly obtained.

Fig. 90 shows the method of finding the curves of penetration for a semi-cylinder intersecting a sphere, as is the case of a cylindrical vault interpentrating a spherical dome, the semi-cylinder standing on a prism, whose width is equal to the diameter of the semi-cylinder, and therefore springs from the line XY. ABC is the plan of the sphere, and ADEC the plan of the cylinder. Draw the sections of the sphere and cylinder as B_1GF and DHE respectively. Divide the line DE

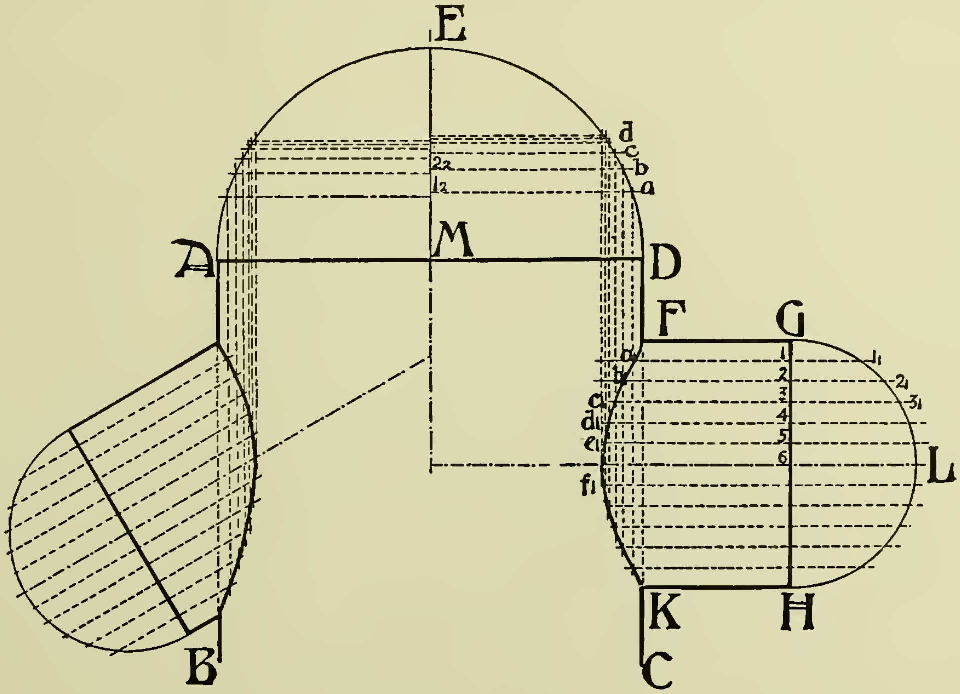


FIG. 89.

The curves of penetration of the cylinder with the other three faces of the prism are also shown, but the construction lines have been left out to prevent confusion of the diagram.

Fig. 89 shows the method of finding the curve of penetration of a semi-cylinder intersecting another semi-cylinder, as is the case of vaults. ABCD is the plan of the large cylinder, and AED is its section. FGHK is the smaller cylinder, and GLH its section. Divide GH into any convenient number of equal parts 1, 2, 3, 4, etc., and through these points draw lines parallel to the axis of the smaller cylinder and cutting the section at 1_1, 2_1, 3_1, 4_1, etc. From ME cut off parts $M1_2$, $M2_2$, $M3_2$, $M4_2$, etc., equal to 11_1, 22_1, 33_1, 44_1, etc. Through 1_2, 2_2, 3_2, 4_2, etc., draw lines parallel to AD, cutting the section of the large cylinder at *a*, *b*, *c*, *d*, etc., and from *a*, *b*, *c*, *d* draw lines parallel to FM and cutting the lines through 1, 2, 3, 4, etc., at a_1, b_1, c_1, d_1,

into any convenient number of parts at 1, 2, 3, 4, etc., and through these points draw lines parallel to BH, cutting DHE at 1_1, 2_1, 3_1, 4_1, etc.

Set the heights 11_1, 22_1, 33_1, 44_1, etc., up XG above the springing line XY, as $X1_2$, $X2_2$, $X3_2$, $X4_2$, etc., and through 1_2, 2_2, 3_2, 4_2, etc., draw lines parallel to B_1F cutting the circumference B_1GF at *a*, *b*, *c*, *d*, etc., respectively. Through *a*, *b*, *c*, *d*, etc., draw lines parallel to GK, cutting BH at a_1, b_1, c_1, d_1, etc. With O as centre and Oa_1, Ob_1, Oc_1, Od_1, etc., as radii draw concentric arcs, cutting the lines drawn through 1, 2, 3, 4, etc., at a_2, b_2, c_2, d_2, etc. A curve drawn through the points a_2, b_2, c_2, d_2, etc., gives the plan of the curve of penetration required.

To find the curve of penetration along BH, draw $f^1{}_2E_1$ and mH_1 representing the springing line and crown line respectively of the semi-cylinder. Project the points a_2, b_2, c_2, d_2, etc., to $a^1{}_2$, $b^1{}_2$, $c^1{}_2$, $d^1{}_2$ on the line $f^1{}_2E_1$

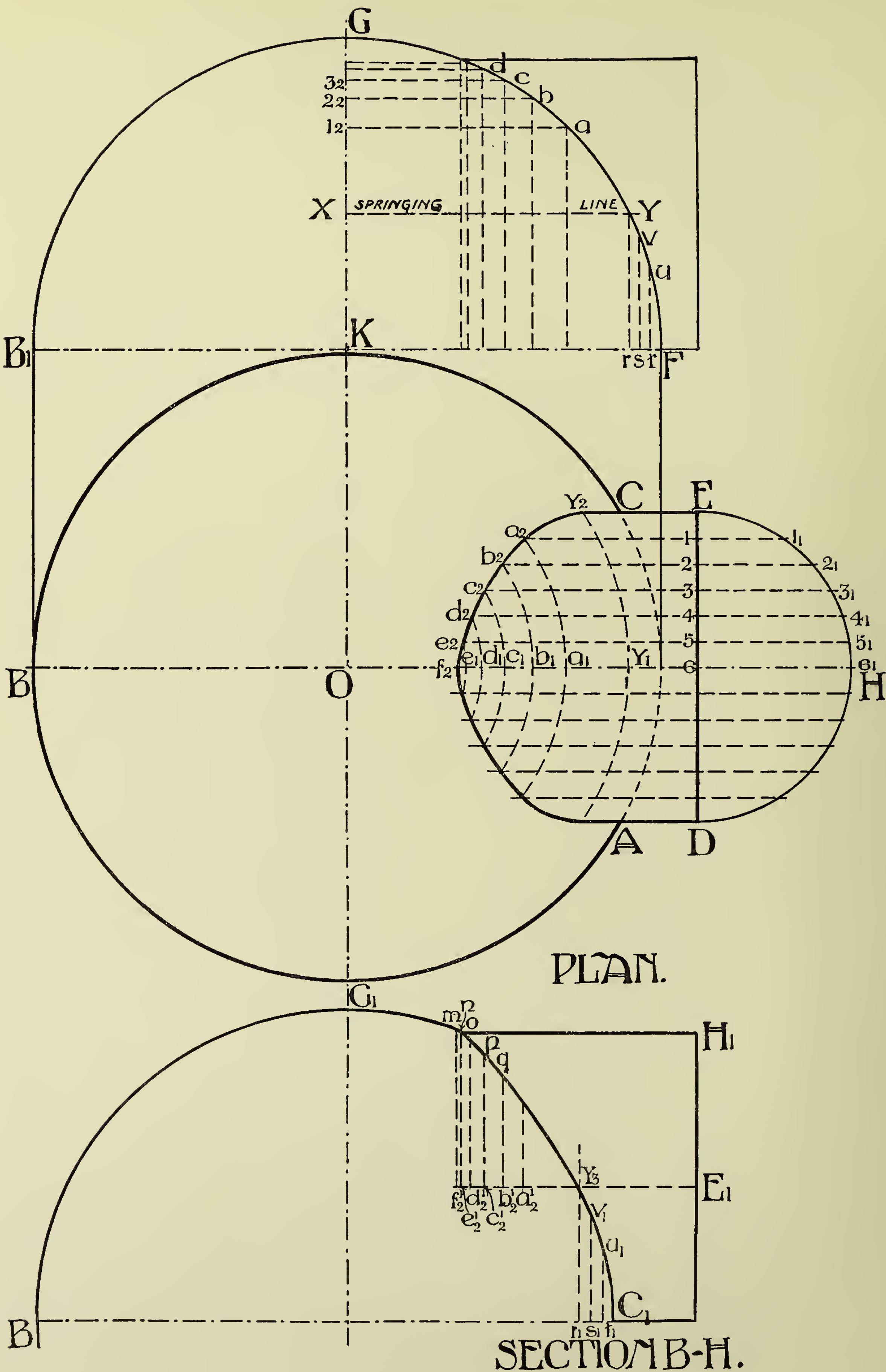

G
d
c
b
a
X
SPRINGING
LINE
Y
v
u
B1
K
F
C
E
A
D
B
O
H
PLAN.
G1
H1
E1
C1
SECTION B-H.

Fig. 90.

and set up the heights $b^1{}_2q$, $c^1{}_2p$, $d^1{}_2o$, $e^1{}_2n$, etc., making them respectively equal to 11_1, 22_1, 33_1, 44_1, etc. A line drawn through m, n, o, p, q, and Y_2 gives the curve of penetration of the semi-cylinder with the dome.

The curves of penetration below the line $f^1{}_2E_1$ is found in the following manner. Divide rF and r_1C_1 each into 3 equal parts at s, t and s_1, t_1 respectively, and erect the perpendiculars sv, tu, s_1v_1, and t_1u_1. Make s_1v_1 equal to sv, and t_1u_1 equal to tu. A line joining Y_3 v_1 and u_1 will give the required curve of penetration on the section BH.

The curve for the penetration of the prism with this hemisphere on plan is obviously a straight line.

Fig. 91 shows an example of two semi-cylinders of the same span intersecting at right angles. The plan of the lines of intersection are obviously straight lines in this case. It will be necessary in working the stones for such a vault, to determine the curve of penetration along one of these diagonal intersection lines. This is done in the following manner: Divide the diameter of either vault up into any number of equal parts as at a, b, c, etc., and through a, b, c, etc., draw lines parallel to the axis of the vault to cut the circumference of the vault in a_1, b_1, c_1, etc., and the diagonal XY at a_2, b_2, c_2, etc. At a_2, b_2, c_2, etc., draw lines at right angles to XY, making a_2a_3 equal to aa_1 and b_2b_3 equal to bb_1, and so on. A curve drawn through the points a_3, b_3, c_3, etc., gives the required curve of the section along XY.

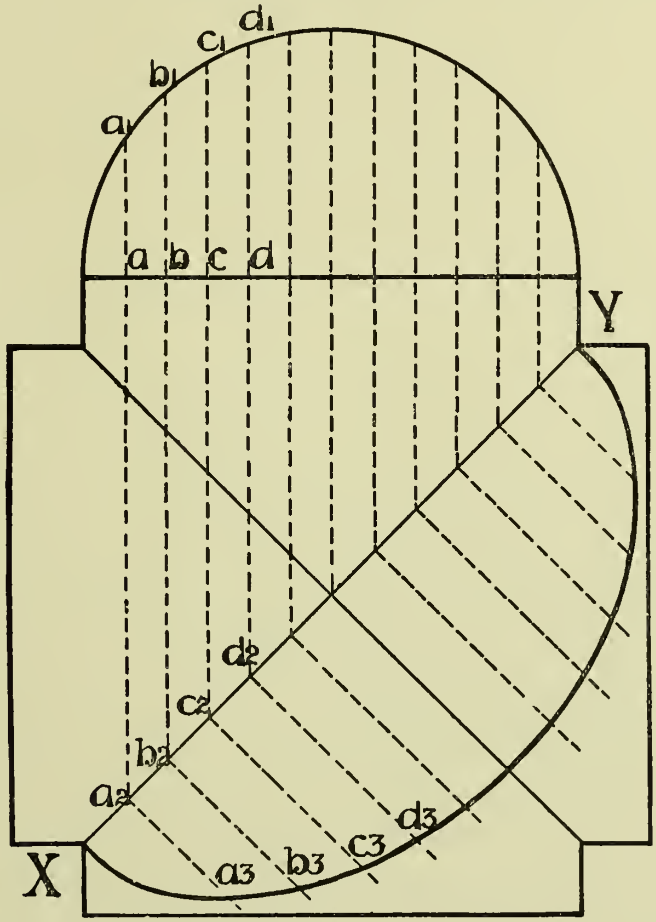


Fig. 91.

CHAPTER VII

ARCHES—PLANE

(*Contributed by Walter Hooker*)

The nature of the various forms of arches and the technical terms used in connection therewith have already been explained under the head of Arches in Volume I. of this work, and need not therefore be repeated here.

A Segmental Arch is struck from a centre at some convenient point below the springing line (or junction of the arch with the supports), and the voussoirs are struck from this centre, the intrados being divided into

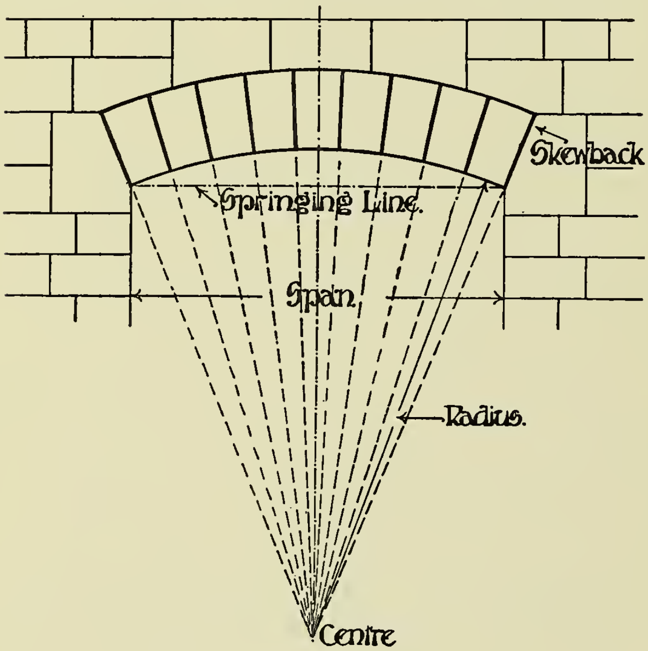


Fig. 92.

a number of equal parts to mark the position of the joints as shown in Fig. 92.

A Semicircular Arch is somewhat similar to the above, with the exception that the centre is on the line of the springing and the radius is equal to half the opening. The curve of the intrados thus dies into the vertical faces of the supports, as shown in Fig. 93.

It is customary, though not universal, to table the upper surfaces of the voussoirs so that the arch ring may bond in with the coursing of the plain wall, thus adding stability to the work. Sometimes the extrados is cut to the same curve as the intrados, as in the case of the segmented arch shown in Fig. 92, but this renders the work less homogeneous than if tabled surfaces are used. On the right-hand side of Fig. 93 the tabling is shown set out from the semicircular dotted line, but this method makes the courses

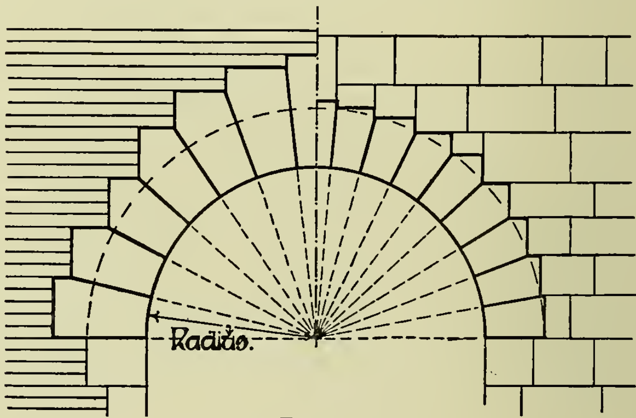


Fig. 93.

of the wall unequal in height. The method of setting out shown on the left-hand side allows greater latitude of adjustment of the courses.

Three-centred Arches.—One method of setting out a three-centred arch is shown in Fig. 94.

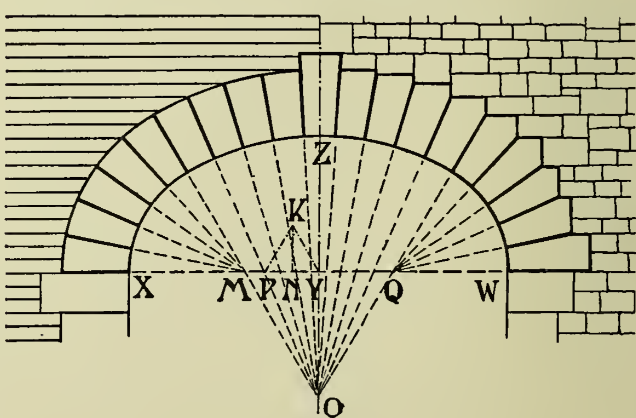


Fig. 94.

Take XW as the span and YZ as the rise.

Let YP = the difference between XY and YZ, and on YP construct an equilateral triangle YPK. Bisect the angle XKP by a line PN cutting the line XY in N. Mark off NM on the line YX = KN, and from YW cut

off a part YQ equal to YM ; and with MQ as base describe an equilateral triangle MQO.

M, Q, and O are the centres for the arch. If OM and OQ are produced they will meet the arcs at their junctions. The joints above the intersections of the greater and lesser curves are struck from O, and the others (or those approaching the springing) from M and Q.

It is an obvious fact that an infinite number of different three-centred arches can be constructed ; so long as the centres of the side segments are on the springing line and the centre of the middle segment is on the centre line of the arch.

It should be noted, however, that the rise should be at least equal to one-third the span, otherwise the arch will be weak.

Elliptical Arches.—Take the distance between the abutments, as at AB (Fig. 95), and equal to the span and bisect it at C. Draw CD perpendicularly to AB and equal to the proposed rise of the arch.

The curve of the intrados is struck by means of a

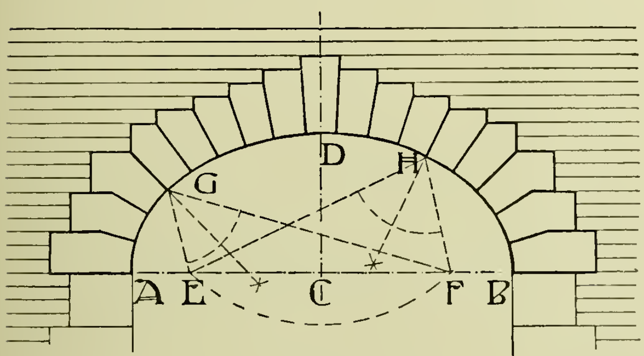


Fig. 95.

trammel, or a number of points are found upon the curve by means of a lath of wood used as a trammel.

A lath is cut whose length AC (see Fig. 96) is equal to half the major axis AB of the ellipse, and a point J is marked on it so that AJ = CD = half the minor axis DE. The lath may then be placed in any oblique direction, so long as the marked points, as C_1 and J_1, lie on the minor and major axes respectively, when the extremity A_1 will mark a point on the circumference of the ellipse. A succession of points thus obtained will outline the ellipse.

Another good method of drawing ellipses is as follows (see Fig. 97):—

Draw two semicircles, one with radius equal to the rise, the other with radius equal to half the span.

Divide the circumference of each semicircle into the same number of equal parts, as in Fig. 97. From each divisional point in the larger circumference draw vertical lines. From the divisional points of the smaller circumference draw horizontal lines to cut the vertical lines. The crossings of these lines mark points on an ellipse.

To obtain the joints, the foci E and F (Fig. 95) must first be found. This is done by striking an arc from the centre D with a radius equal to half the major axis of the intrados, cutting the springing line in E and F. Divide the intrados into a convenient odd number of equal parts. Join each of these points to both foci, and bisect the angle between each pair of lines. The bisecting lines give the direction of the joints. The operation is shown in Fig. 95. All the other joints have been found in a similar manner. The

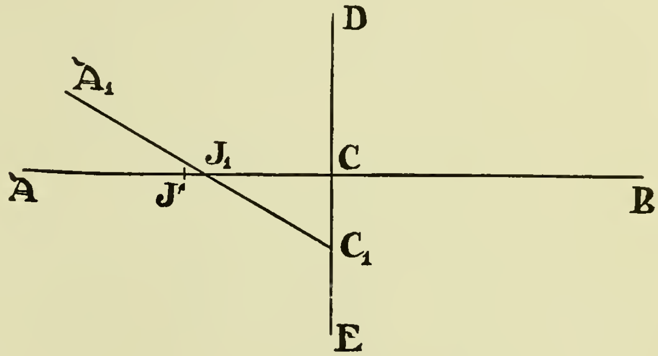


Fig. 96.

joints will be found to be normal to the curve of the intrados.

The elliptic arch has been described in previous paragraphs For estimating the length of its semi-circumference, the following computation may prove useful:—

Let A be the transverse diameter and B the conjugate ; then $\sqrt{\frac{A^2 + B^2}{2}} \times \pi$ = the circumference, and consequently half of this gives the desired dimension $\pi = 3{\cdot}14159$.

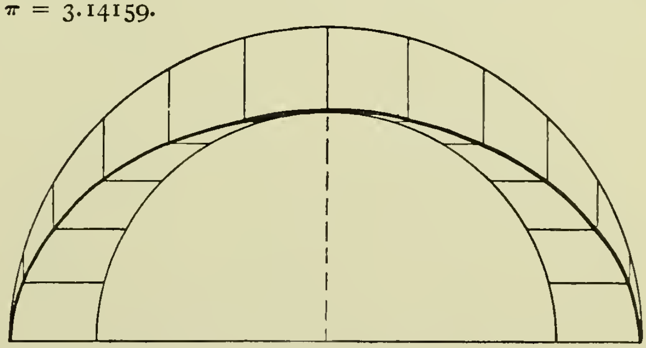


Fig. 97.

Pointed Arches are such as form a point at their apex, as shown in Figs. 98, 99, and 100. The method of setting out the various forms of pointed arches is as follows:—

Lancet Arches.—Let AB (Fig. 98) be the opening between the abutments and also the springing line, and CD (greater than AB) the apex height. Join AC and bisect in E.

From E draw EG at right angles to AC, cutting AB in G. G is the centre of the arc AC. The other centre is found in the same way, as shown at H.

In this case it is seen that the centres fall without the abutments, causing the apex of the arch to be acutely pointed; for which reason this type of arch is termed a Lancet Arch.

Equilateral Arches.—Fig. 99 shows an arch in

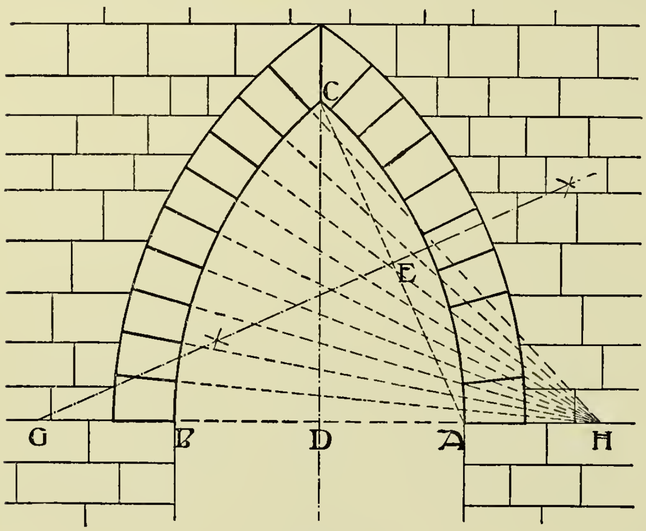


Fig. 98.

which the centres fall on the springing points A and B. In this case the triangle ABC is equilateral, and hence such an arch is termed an Equilateral Arch.

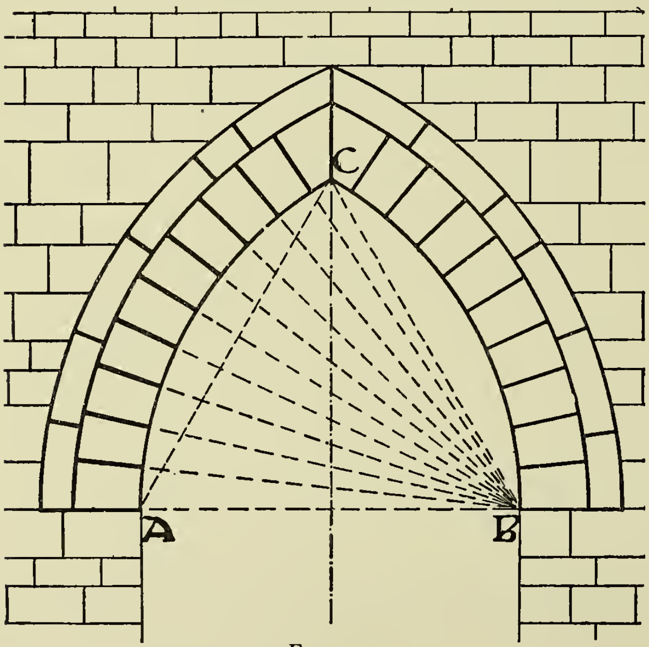


Fig. 99.

Depressed or Drop Arches.—This name is applied to pointed arches with the centres within the abutments, as in Fig. 100.

The joints in all three cases radiate as shown from the centres from which the arches are struck.

Four-centred Arch.—Fig. 101 shows the method of setting out a four-centred arch. The centres of the lower portion of the arch are on the springing line, while the centres of the upper portions are below it.

The joints must radiate from the centres from which the curves are struck, as shown in the figure. It should be observed that Fig. 101 shows but one case of the infinite number of four-centred arches that may be

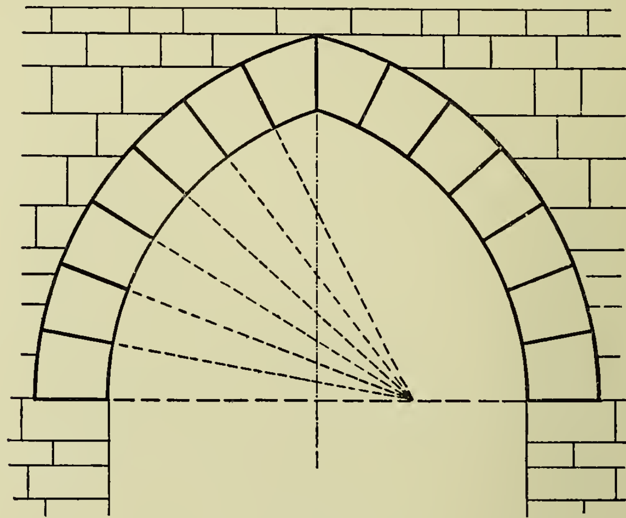


Fig. 100.

found. So long as there are two centres such as A and B upon the springing line, and two centres such as C and D below the springing line, D being collateral with A, and C with B, a satisfactory four-centred arch may be drawn.

Parabolic Arches.—Let AB (Fig. 102) equal the

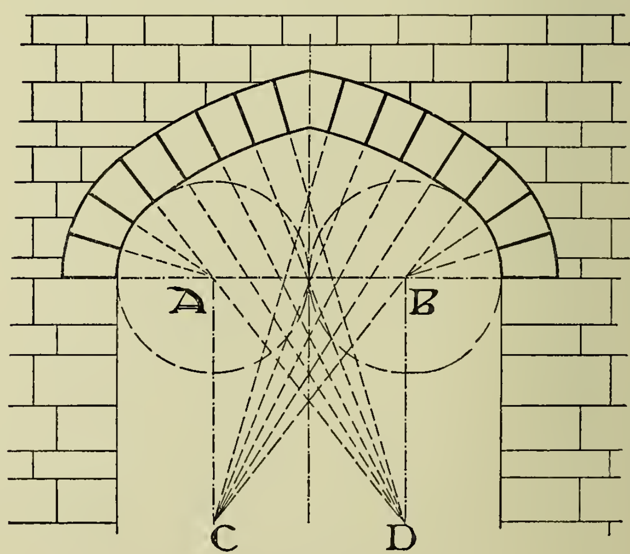


Fig. 101.

span, and draw FD bisecting AB in C and perpendicular to it. CD is the rise and CF is made equal to CD.

Take a point E on AB produced, make EA = AC, and join ED and EF. Divide EF and ED into any convenient number of parts in 1, 2, 3, 4, 5, etc. Join 6 to 6. 5 to 5, 4 to 4, etc. A curve drawn tangentially to all these lines will be a parabola. Half this curve is used

for one side of the arch in Fig. 102. The other half of the arch from D to B has been found by the same method.

Arches are sometimes made of the form shown by the curve DAF placed vertically.

To find any joint of the voussoirs of the arch, divide the intrados up as before, and from each of these points drop perpendiculars on to AB the springing line, such as GH on the right-hand side of Fig. 102. Produce CB to K, make BK = BH. Join KG. Then KG is a tangent to the curve; and at K erect a perpendicular to GK. This will be the pitch of a joint at point G. The pitch of the joints at all the other points is found in a similar manner.

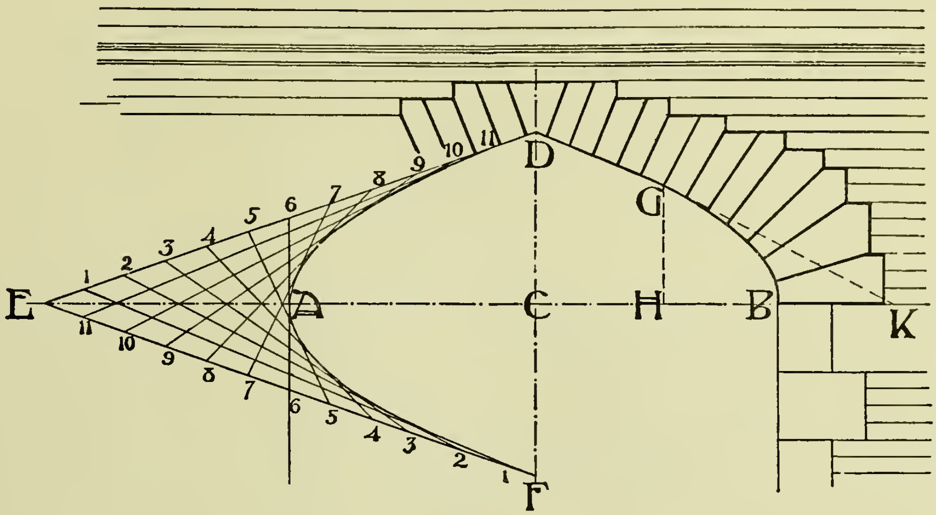


FIG. 102.

HYPERBOLIC ARCHES.—Let AB (Fig 103) be half the span and BC the rise. Draw AE = $\frac{2}{5}$ of CB, and parallel to it. Join EC. Divide AE and CE into the same number of equal parts, as 1, 2, 3, 4, etc. Join 1 to 1, 2 to 2, 3 to 3, etc.

A curve drawn tangentially to these lines will give the outline of the intrados of the required arch. The direction of the joints is found as shown for parabolic arches.

Another method of striking a similar curve is shown in Fig. 104. Let AB be the $\frac{1}{2}$ span, and BC the rise. Prolong AB to D. Make AD = AB. Draw CE parallel and equal to AB. On CB mark off any number of equal parts in points 1, 2, 3, 4, etc., and join these to D. On CE mark off the same number of equal parts and join them to A. A line drawn through the crossings of these lines as shown on the left-hand side of Fig. 104 will give the curve of one side of the arch. The other side can be found in the same manner.

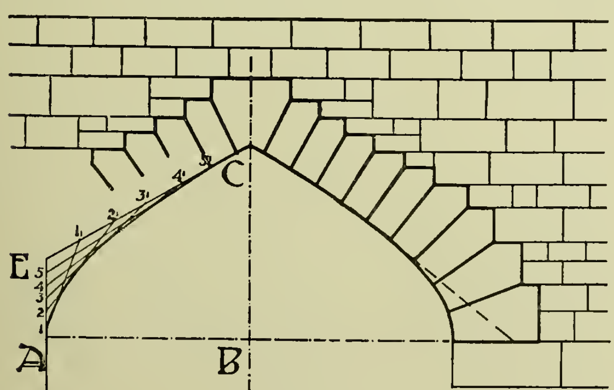


FIG. 103.

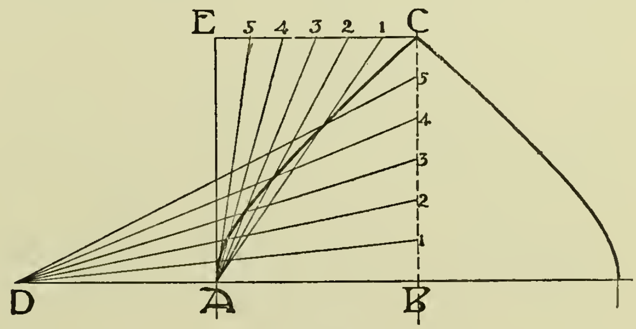


FIG 104.

OGEE ARCHES.—These arches are variously described as of 1, 2, 3, or more parts or divisions of the span or opening.

To draw an ogee arch of one part. Let AB (Fig. 105) be equal to the span or opening at the springing line, and bisect it in C. Draw CD, the centre line, at right angles to AB. Let E be the most prominent point of the hood-mould, as shown on the section of the moulding, and with centre C describe a quadrant EF. Bisect the quadrant EF in G. Through G draw EG prolonged to cut CD in H. Draw HK parallel to AB, and through G draw CGL, cutting HK in L. The point L is the centre of the upper or reverse part of the ogee arch.

For an ogee arch of three parts divide the span into three parts (see Fig 106). Find the centre C as before,

and erect a perpendicular CD. Then with centre C and radius CE describe the quadrant EF, and divide EF into four equal parts. Join E to G, the last division of EF, and produce to cut CD at H. Through H draw HK parallel to EC. Join CG and produce to cut HK in K. This fixes the centre for the upper part of the ogee. In this instance the ogee is flattened, and naturally becomes more so the more points the span is divided into.

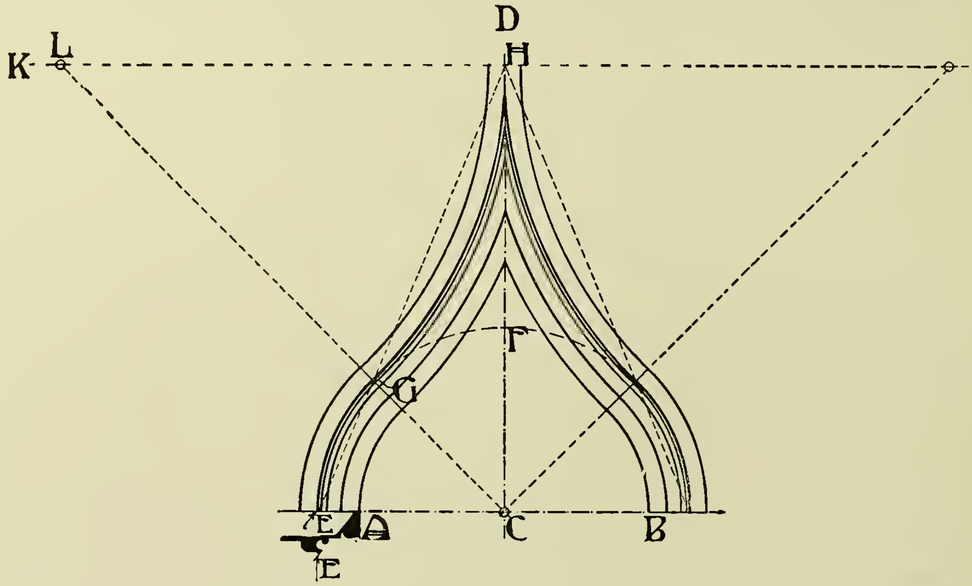


FIG. 105.

The design of ogee arches admits of infinite variety. Thus in Fig. 107 an arch is shown in which a similar process is employed to that described above, but AB, BC, and CD have all been made equal; while in Fig. 108 an arch is shown where the span has been divided into eight equal parts, the centres taken where shown, while the lower curves are divided into five equal parts.

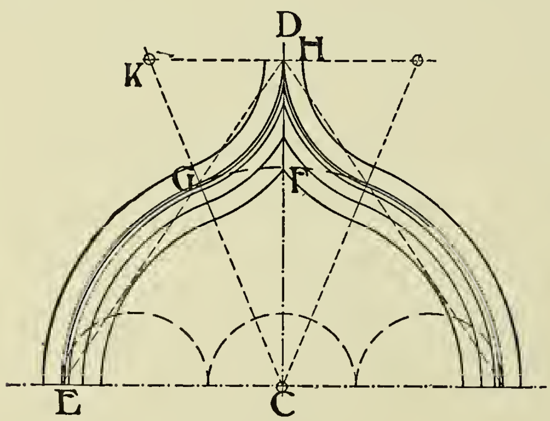


FIG. 106.

The object of taking the most prominent point of the hood-mould when striking the lower arcs is to make the mitre at the apex work conveniently. This, however, though usual, is not a hard and fast rule, and the lower arcs may be taken from any other point if the design permits of it.

FLAT ARCHES.—The use of a whole stone without joints, *i.e.* a lintel, is the most economical method of carrying a load over a small opening. Where, however, openings are large,—or from the nature of the stone scantling lengths are inadmissible,—various systems of jointing are practised, as shown below.

Radiating Joints (Fig. 109).—In this case the skew-backs are projected down to meet at the point C, from which the dotted curve AB is struck. The arc is divided up into an odd number of equal parts as in the case of a segmental arch. Lines radiating through these points from centre C mark the joints.

Stepped Joints.—The same method is adopted in the case of stepped joints (Fig. 110). The joints are, however, not continuous, but, as the name implies, are rebated or stepped. The work is more expensive, but is certainly very stable.

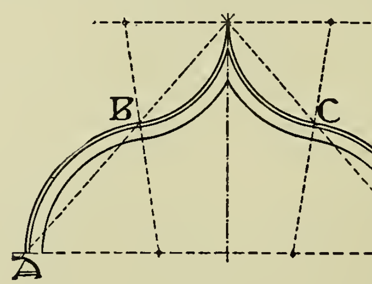


FIG. 107.

Joggled Joints.—Another form, somewhat similar, is termed joggling, and consists in leaving a rounded projection on one face of the joint, and a hollow on the corresponding face of the adjacent stone, as shown in

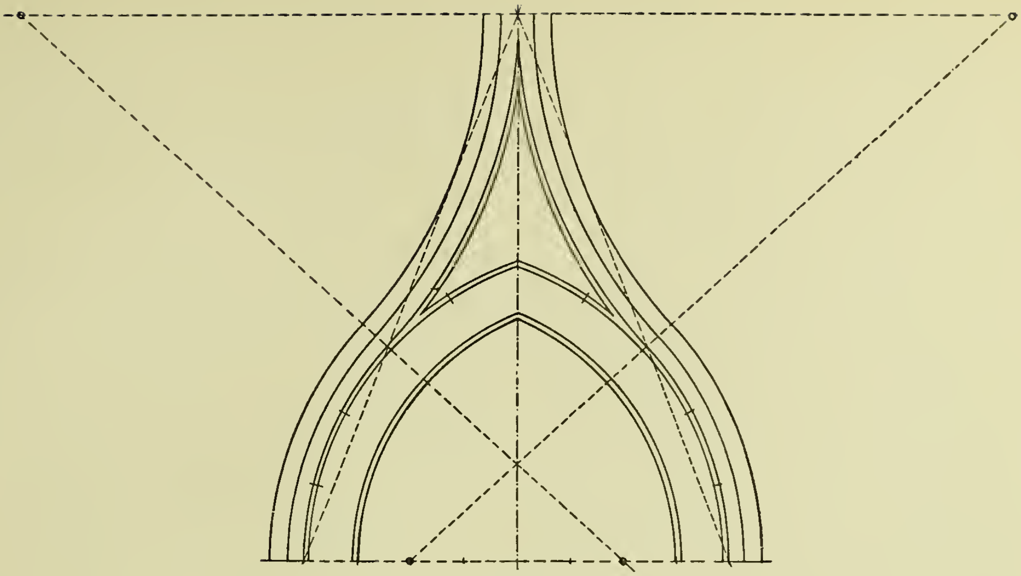


Fig. 108.

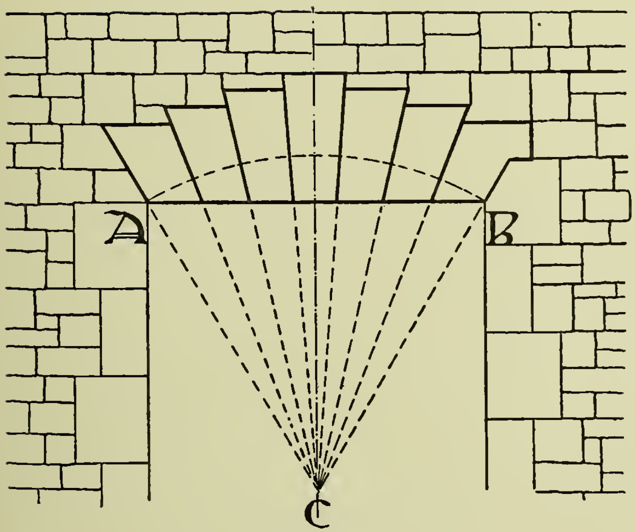


Fig. 109.

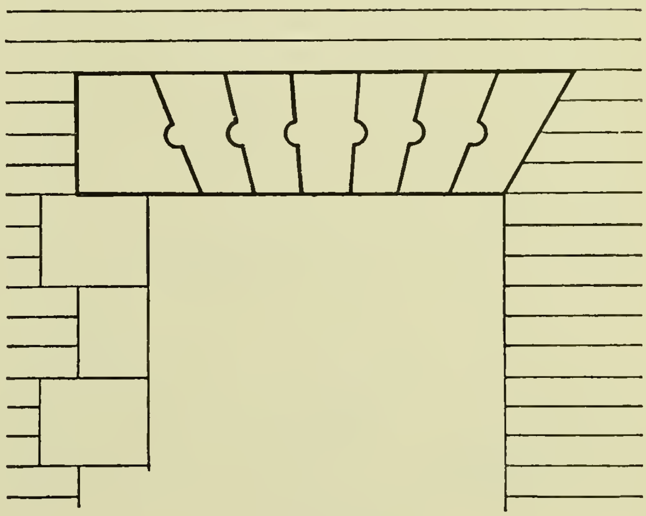


Fig. 111.

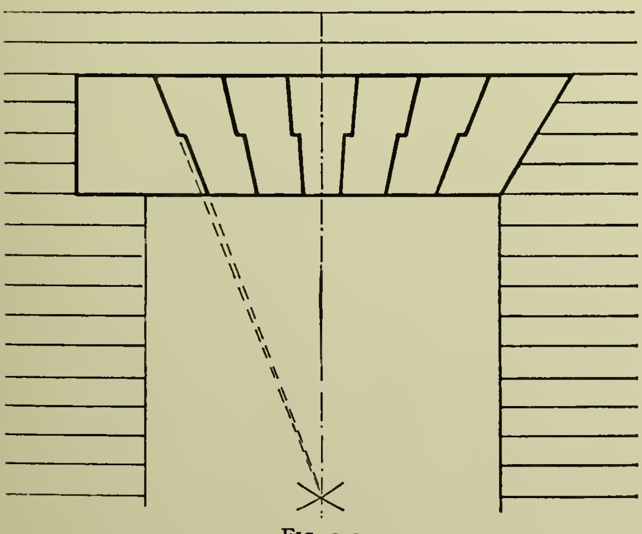


Fig. 110.

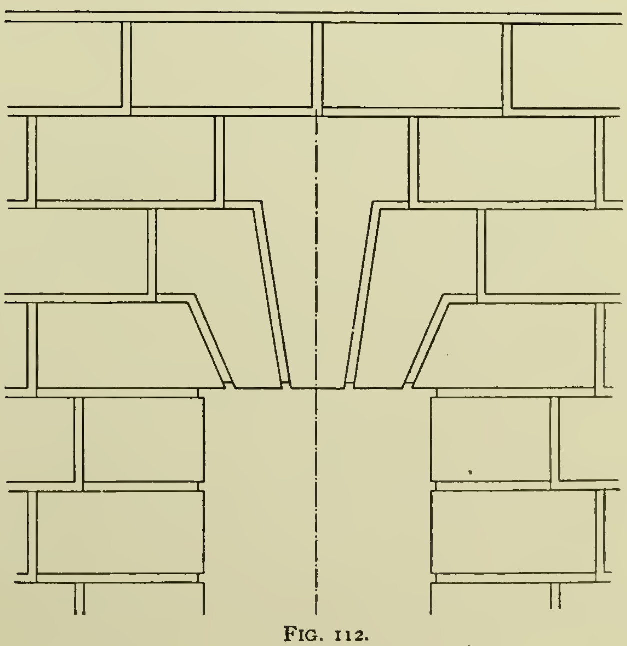


Fig. 112.

Fig. 111. This is perhaps more applicable to terra-cotta work.

For small openings some method such as is shown in Fig. 112 may be adopted. This is expensive on account of waste of stone in working, but it gives a very fine effect when well treated.

To set out the stones for cutting to the shapes required for the various positions of a square-headed window, see Fig. 113, which shows the elevation of a window head formed as a flat arch. In order to show the method of working the stones, take, for example, the angle stone AIBCD, whose elevation is its face mould. The bed mould ADFE is simply a plan of the above AIBCD with the moulding and rebate worked upon it.

The joint mould would be a projection on the raking plane IB, making the moulding somewhat elongated. This joint is set out by applying the mould to the square end of the stone, as shown by the dotted line IK, and cutting the mouldings back to the mitre line IH, the vertical portion of the moulding being worked up from the bed to meet a line drawn horizontally from the point I, and then continued as necessary to form the mitre with the horizontal moulding. The bevel is then set to the raking plane IB and the stone cut back to the joint.

To illustrate this more clearly, Fig. 113 shows an isometric view of the stone AIBCD, the plane face $B_1C_1D_1$ representing the similarly lettered face BCD on the face mould.

The letters A_1, K_1, Y, and V represent angles of the

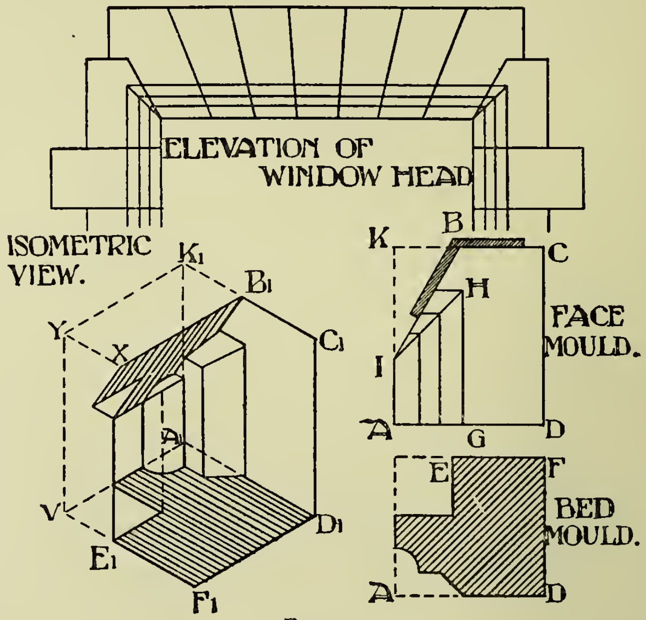


FIG. 113.

squared block from which the stone is cut, which have to be removed in bringing the stone to its required form.

CHAPTER VIII

ARCHES—CIRCULAR ON PLAN, OBLIQUE AND BATTERED

(*Contributed by* WALTER HOOKER)

A PROBLEM of some difficulty is encountered when an arch has to be constructed in a wall which is circular on plan, or in a battered wall, or when the axis of the arch runs obliquely to the face of the wall. The following examples will show how to set out such arches, and how to work the various stones for them :—

Arched openings in circular walls.—To set out and construct arched openings in circular walls is a problem frequently met with in buildings of the rotunda class, or circular apses of cathedrals, etc.

Fig. 114 shows an opening in a circular wall with an arch surmounting it having the intrados of its outer face semicircular on development.

In this instance the reveals of the opening radiate from the centre, from which the plan of the wall is struck, and as the external arch is semicircular and the soffit at the crown is horizontal, the interior arris of the arch will form an elliptic curve on development, with half its major axis equal to the height of the arch from springing line to the crown, and its minor axis equal to the length of the arc BC on plan.

Fig. 114 shows a plan of the opening with centre line OX, where AB and CD are the reveals.

On any horizontal line YY, with X_1 as centre and with radius equal to the length of the arc AX, set up the quadrant A_1E. Next set out the points B_1, etc., making B_1X_1 and C_1X_1 each equal to half the length of the arc BC, and draw the half ellipse B_1EC_1.

These two curves A_1E and B_1E will give the development of the outer and inner line of the stones composing the arch of the soffit. Divide the outer curve A_1E into any uneven number of equal parts required to form the voussoirs, and draw lines radiating from the centre X_1, which will give the joints. From the points of contact of the joints with the outer arc draw lines parallel to the springing, and cutting the ellipse as shown. These will give the line of the bed joints on the soffit.

Draw GH on plan radiating from the centre O, making AG equal to the required depth of the arch. Make X_1G_1 on the springing line equal to the arc XG on plan, and with the centre X_1 and the radius X_1G_1 describe the arc G_1K. This arc is the development of the extrados of the outer face of the arch. Make X_1N_1 on the springing line equal to half the arc HN on plan, and X_1M equal to X_1G_1. Then with X_1N_1 as minor axis and X_1M as major axis describe the quarter ellipse MN_1 shown dotted on elevation. This quarter ellipse is the developed elevation of the internal extrados. Complete the outline of the bed joints, which will be parallel to the springing line on the extrados and will radiate from the centre X_1 on the internal face as indicated by the dotted lines on the right-hand side of the developed elevation. Project the points *a*, *b*, *c*, *d*, etc., horizontally

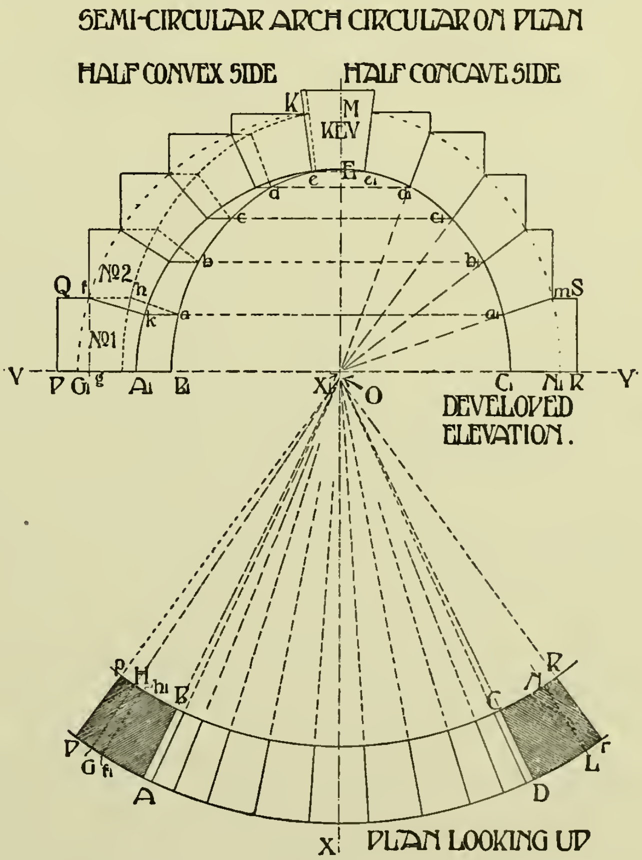


FIG. 114.

on to the curve EC_1 at a_1, b_1, c_1, d_1, and e_1 respectively, and through a_1, b_1, c_1, d_1, etc., draw the radial joints.

The arch may be constructed with the extrados and intrados forming concentric circles, as described up to the present. In practice, however, it is almost invariable to step the extrados so as not only to make a sounder job by bonding in the arch stones to the adjacent masonry, but also to save the labour

of working twisted faces on the stones next to the arch wing. For this reason a stepped extrados is shown in the figure, the steps being set out upon the developed elevation. It will now be seen that on the left-hand side of the line XX_1 a front developed elevation of the arch has been drawn, while on the right-hand side of XX_1 a development of the internal face is shown.

From f drop the perpendicular fg on to YY, and from the arc XP cut off a part Xf_1 equal to X_1g. A line drawn from f_1, radiating from O, marks the position on plan of the joint f_1h_1 in the elevation. In the same way all the other bed joints can be found, thus completing the plan. The object of the above drawings is to find the shape of the moulds from which the stones are to be worked. For the sake of example the springer on the left-hand side of the arch will be considered, every developed elevations respectively of the stone, as shown in Fig. 114.

In working stone No. 1 a roughly square block is taken and the top and bottom beds are worked parallel to each other. The bed mould is then scribed upon both beds, as shown at T, Fig. 115, where $\alpha\beta\gamma\delta\epsilon\phi$ represent the block from which the stone is cut, with the bed mould scribed upon its upper surface. Next, the stone is cut along the face Pp and Ka, care being taken to keep PQ vertical. The convex and concave faces are next worked, being boned across from the top and bottom beds, the stone then presenting the appearance of U, Fig. 115. The face moulds are then bent against and scribed on to their respective faces and the joint $fKam$ is boned across. It should be noted that there will be a slight twist on this joint. A chisel

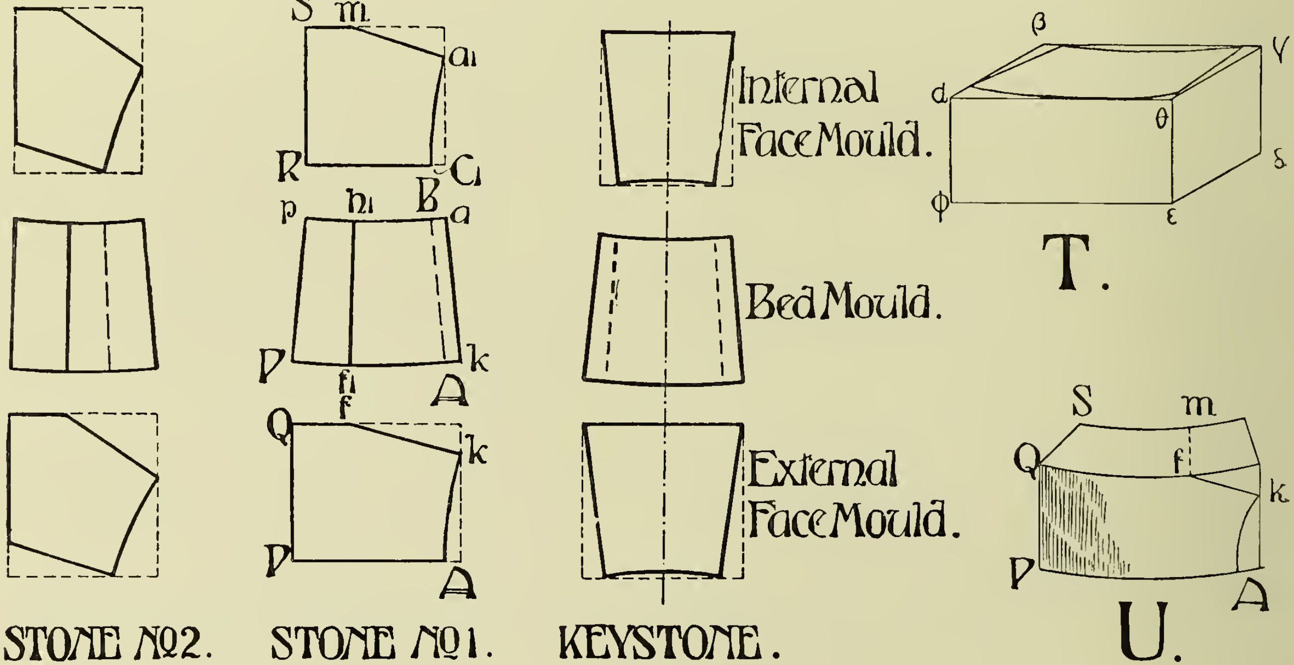


FIG. 115.

operation required to bring it from the rough block to the required form for setting in the arch being explained in order.

To set out the moulds.—For each stone a bed mould and two face moulds are required, one for the internal face and one for the external face. In Fig. 115 the moulds for the springer and the next stone above and the keystone are shown. The bed mould of the springer is simply a replica of that shown upon plan in Fig. 114, each point of the bed mould being similarly lettered to the plan of the springer in Fig. 114. The external face mould is similarly a replica of stone No. 1, as shown on the left-hand side of the developed elevation, and the internal face mould is a replica of the same stone on the right-hand side.

The moulds of stone No. 2 and of the keystone are also replicas of the plans, and the external and internal draft is cut on both faces along the lines Ak and C_1a_1, and the stone is completed by boning the soffit across.

The same method of procedure is carried out for the remaining voussoirs, the keystone being a little different, as the soffit and the outer and inner face only would be curved. The soffit would be in this instance of very flat camber and slightly twisted. In actual practice the joints would be slightly spiral.

Oblique and Battered Arches—To find the beds, faces, and moulds of the stones in an oblique arch, one face of which has a batter of 10 degrees off the vertical.

Let ABCD (Fig. 116) be the plan of an oblique opening in a plane wall battered on the external face, ADEF and BCGH being the plans of the bed joints of the springers.

Let A_1JB_1 be the elevation of the arch as projected

on to a plane parallel to the face of the wall. This elevation is made semicircular.

Divide the arc A_1JB_1 into 7 (or any other odd number) equal parts, and draw radiating lines from the centre X through the points thus found, as a, b, c, d, e, and f. These lines will show the joints of the voussoirs of the arch. Complete the elevation. The extrados may be stepped as explained in Chapter VII., or it may be a semicircle as shown.

At H_1 draw H_1K perpendicularly to F_1H_1.

From H_1 draw H_1 L, making an angle of 10 degrees with H_1K to indicate the batter of one face of the arch.

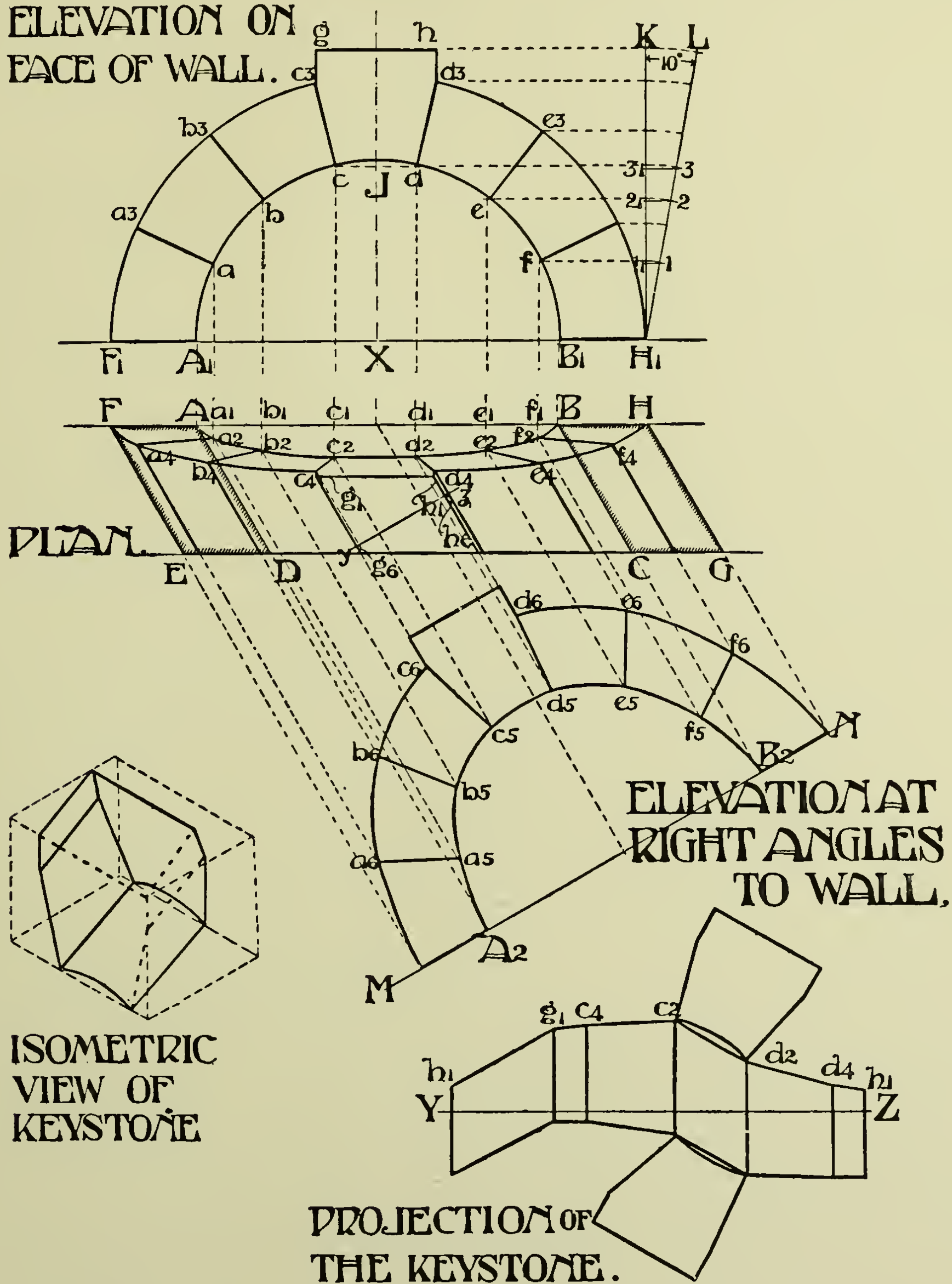


FIG. 116.

From the points a, b, c, etc., let fall perpendiculars on to and beyond AB on plan. From the points a, b, c, etc., draw lines parallel to A_1B_1 intersecting H_1K, and with H_1 as centre describe arcs from these intersections cutting the battering line H_1L at 1, 2, and 3. From 1, 2, and 3 draw horizontal lines cutting H_1K at 1_1, 2_1, and 3_1. Then a_1a_2 and f_1f_2 on plan are each made equal to 11_1; b_1b_2 and e_1e_2 are made equal to 22_1; c_1c_2 and d_1d_2 are made equal to 33_1.

A curve drawn through a_2, b_2, c_2, etc., will give the plan of the intrados. The points a_4, b_4, c_4, etc., are found in a similar manner, and a line drawn through

them will give the extradosal line (or plan of the extrados).

To obtain the rectangular section through the arch, let MN be drawn at right angles to AD produced. Project the points of the voussoirs both of the intrados and extrados to meet MN and parallel to AD. Mark off the heights of the joints—shown above A_1B_1 in elevation—above MN, as at a_5, b_5, c_5, etc., and connect as before. The intrados of the arch will then be defined by drawing a curve through the points a_5, b_5, c_5, etc., as in the illustration. The points a_6, b_6, c_6, etc., are found in a similar manner, and the elevation is completed as shown.

To project the faces of any voussoirs :—

Take, for example, the keystone. Draw any convenient straight line *yz* at right angles to AD on plan through the stone required, and with this as a base take the distances above and below, and mark the same above and below any convenient straight line YZ ; the distances of the faces along the line of YZ being transferred from the upper elevation as h_1, g_1, c_4, c_2, d_2, d_4, and h_1.

These points being joined and the curved surfaces transferred will give the bed moulds and joints. The faces are found by rotating the lines on a base such as the soffit mould, until they form the true shape of the stone as shown in the projection.

If the development is set out on the above lines on a piece of cardboard and rotated as above described an accurate model of the stone should be the result.

An isometrical view of the apex stone is also shown with the projected faces in true juxtaposition, enclosed in its corresponding block of stone.

A somewhat similar though rather more complex example of an oblique arch in a battered wall is shown in Fig. 121, where the arch is shown penetrating a semicircular vault.

CHAPTER IX

VAULTING

(*Contributed by* WALTER HOOKER)

A VAULT is an arched covering over an apartment. Vaults usually take their name from the nature of the curve forming the intrados of their cross section.

CYLINDRICAL OR BARREL VAULTS

The most simple form of vault is one having its cross section semicircular, as shown at AB in Fig. 118. This form is sometimes carried out with stones of even thickness throughout, and sometimes with stones decreasing in thickness towards the crown of the arch, as the thrust increases from the crown to the springers. Heavy masses of masonry must be provided to form the supporting walls, to ensure stability against the thrust and weight.

The details are simple enough, each voussoir being of regular section, with its beds and faces similar as to bevel except as to the magnitude of the stone. For instance, the bevels for the joints are at a regular angle with the axis in all cases, as are also the face bevels (intrados) which would be parts of the semicircle of the vault.

Fig. 117 represents a stone in perspective, being one of the members of a plain cylindrical vault struck from centre C. The dotted lines described around the stone show the squared block previous to being shaped ready for its final use in the vault.

The dotted line DD represents the axial line of the stone, and serves to set out the bevel or rake of top and bottom beds. The intrados and extrados are cut to bevels set to arcs of circles with centre C.

A further advance is made where side openings or subsidiary vaults are introduced.

Fig. 118 shows the simplest case of the interpenetration of cylindrical vaults, in which the space to be covered is square, the vaults being consequently of equal span and rise. The groins, or intersections of the vault surfaces, form diagonals which on plan are at right angles to one another, and cross from corner pier to corner pier, both on the intrados and extrados. These form straight lines on plan. A section through one of the diagonals from corner pier to corner pier gives a semi-ellipse, as shown in Fig. 118 and explained in Chapter VI.

The method of setting out such a vault is as follows: Draw the plan ABCD, showing the bed joints of the springers and the groin lines. Set up the sections of the vault as shown, divide them up into an odd number of equal parts, and draw in the joints radiating from the centres from which the intradoses are struck. The first joint from the springing line is usually made horizontal, and the second stone has its upper surfaces formed as shown. These lower stones are not invariably treated in this manner, but it is only waste labour to cut away the stones to form the true intersection of the cylinders on the extrados, especially as the load is required at this point to resist the thrust of the vaults ; and, moreover, this method of treating the joints enables the building in which they occur to be carried up and the timber roof constructed before the rest of the vaults are completed under cover.

The joints can now be indicated on plan ; the radial

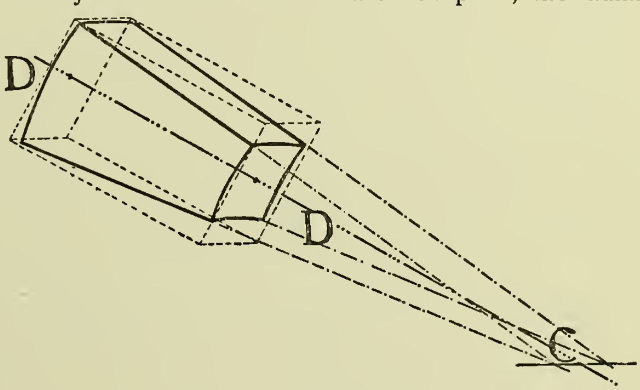


FIG. 117.

joints or beds of the intrados being projected to meet the diagonals for the plan looking up, and those of the extrados being similarly projected for the plan looking down. The plan looking up is shown on the left-hand side of Fig. 118, and the plan looking down is shown on the right-hand side. The transverse joints are made vertical, and those occurring at the groins are drawn in first, and are projected from the junction of the bed joints on the extrados of the section, except in the case of the keystone where the four arms have been made of a convenient length. The other vertical joints are drawn in anywhere so long as they break-joint on plan.

The sections along the intrados and extrados are also shown upon the plan, the dotted lines being ordinates which have been made equal to the ordinates of the cross section taken from the springing line.

To make the drawing clearer, sketches of the three lowest corner-stones and the keystone are shown.

Bed and face moulds of stones Nos. 1, 2, 3, and work the top and bottom bed joints parallel to each other, making the vertical distance between them equal to the vertical height above, as shown on the face mould, and

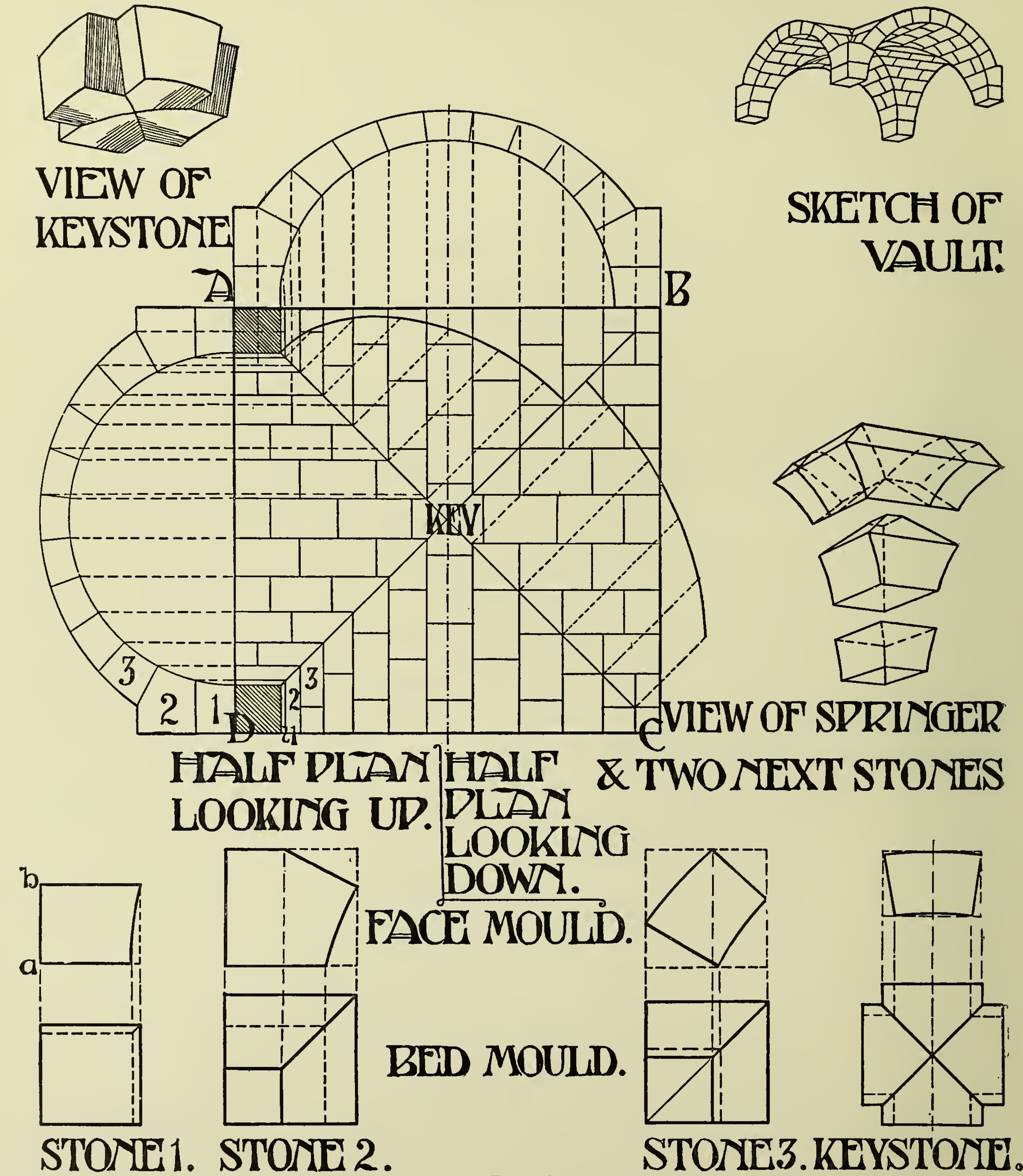


Fig. 118.

the keystone are also shown at the bottom of the figure.

To bring the springer No. 1 to its required shape, scribe on the bed mould Then work the two vertical faces square with the bed, scribe on the face moulds, and work the curved soffits, care being taken to keep

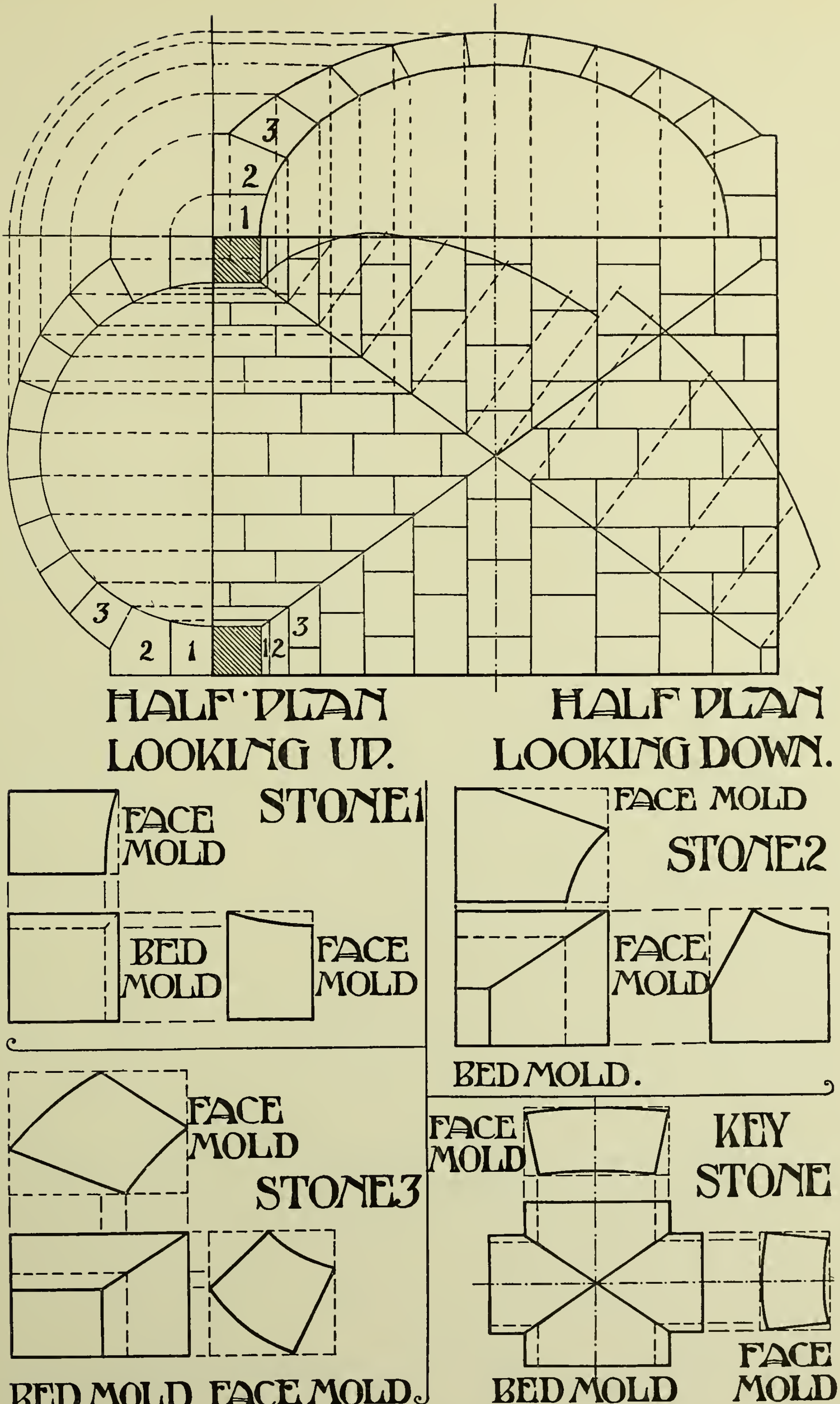

3
2
1
3
2
1
1 2
3
HALF·PLAN
LOOKING UP.
HALF PLAN
LOOKING DOWN.
STONE 1
FACE
MOLD
BED
MOLD
FACE
MOLD
FACE MOLD
STONE 2
FACE
MOLD
BED MOLD.
FACE
MOLD
STONE 3
BED MOLD
FACE MOLD.
FACE
MOLD
KEY
STONE
BED MOLD
FACE
MOLD

Fig. 119.

the groins absolutely true. For stone No. 2, work the top and bottom beds parallel to each other and at the correct distance apart, scribe on the bed mould, and work the two vertical faces, scribe on the face mould and work the splayed surfaces through, and then work the curved soffits, keeping the groins quite true.

In this case only one face mould is required, as both the arches are similar.

Where the space to be vaulted over is rectangular and not a square on plan the vaults may be arranged in several different ways. Either one of the vaults may be cylindrical and the other elliptical, or the smaller arch must be stilted to bring its crown to the same level as that of the larger arch ; or the smaller arch may be cylindrical and spring from the same level as the larger arch—in which case the groins will not cross at the crown. The method of finding the curves of intersection has already been shown in Chapter VI.

Fig. 119 shows a vaulted roof over a rectangular space, in which the smaller vault is made semicircular and the large vault elliptical, to accommodate itself to the smaller vault surfaces. In this case the smaller vault is set out to full in section. The bottom beds of the springers are represented at the corners of the plan, and the diagonals are drawn straight across from corner to corner. The soffit joints are now projected from the section of the smaller vault down upon the diagonals, and the points thus found upon the diagonals are projected up at right angles to the springing line of the larger vault. Portions of these lines are cut off above the springing line equal to the ordinates of the smaller vault above its springing line. A curve drawn through the points thus found gives the intrados of the larger vault. The extrados of the larger vault is then found in a similar method, and the joints are found by joining the ends of the ordinates. The joints on plan are similar to those shown in the case of Fig. 118. The bed and face moulds for the three lowest stones and for the keystone are also as shown on Fig. 118. The shape of these stones is similar to the corresponding stones of Fig. 118, as shown by the sketches.

Fig. 120 shows the case of a vaulted compartment such as would be occasioned by a semicircular vault passing round a circular building. ABCD is the plan. AEB is the section of the semicircular vault, which has been made of even thickness throughout, save for the two lowest stones at each corner, the joints radiating from the centre. Develop the line AOD along A_1OD_1, and by the method of ordinates set up the developed section as shown in Chapter VI. Next find the curves of interpenetration as shown in Chapter VI. Project the joints on the soffit of the smaller vault on to the springing line, as at a, b, c, d, etc.

Using the centre from which the lines AD and BC were struck, draw concentric arcs to pass through the points a, b, c, d, etc., and to cut the line of the groins ; and from the points of intersection thus found draw radial lines as shown to cut the line AOD at a^1_1, b^1_1, c^1_1, d^1_1, etc. Along OA_1 develop the distances Oa^1_1, Ob^1_1, Oc^1_1, etc., as shown at Oa_1, Ob_1, Oc_1 ; and from the points a_1, b_1, c_1, d_1, etc., erect perpendiculars to cut the intrados of the larger vault section. The points of intersection thus found will give the position of the joints on the intrados. The joints on the extrados may be found in a similar manner. The vertical joints are put in as shown in Fig. 118, save that in this case they radiate across the vaults on plan and are concentric with the lines AD and BC along the vault. The smaller vault section may be found in a similar manner. The bed and face moulds for the lowest three stones at the corner A and for the keystone are also as shown in Fig. 118. The shapes of these stones are similar to those in Fig. 118, save that the vertical joints radiate.

A more difficult case is presented in Fig. 121, in which an arched opening penetrates a cylindrical vault, having the external face of the wall at an angle with the axis of the vault and also battering vertically.

Let the angle of skew of the face be 10 degrees and the batter of the wall 1 : 3. Let CB, AD be the lines of contact of the beds of the voussoirs at the springing, and B, J, I, H, G, F, E, A the points at the joints of the stones which form the semicircular arch, the centre being K.

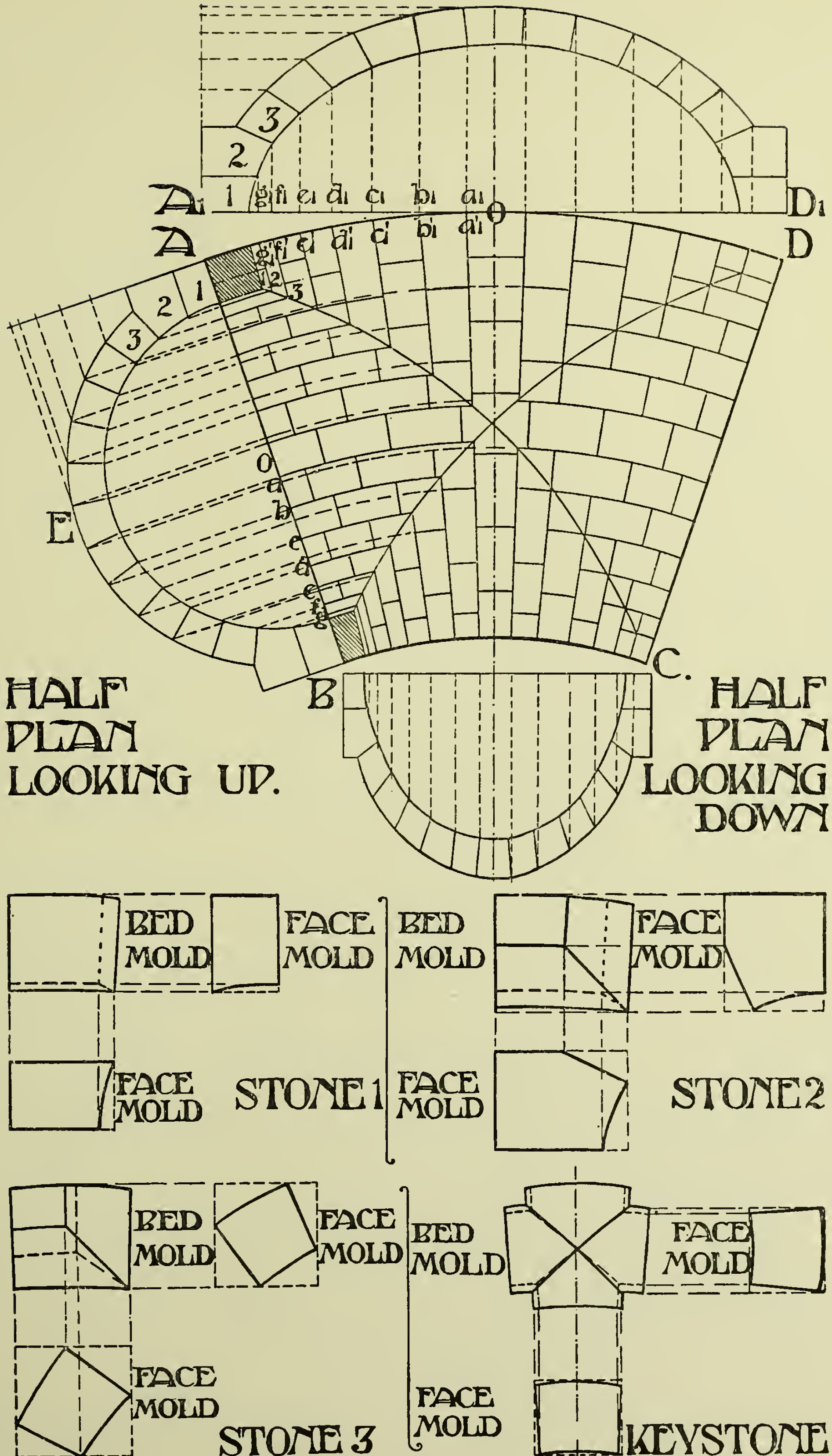
Project lines parallel with the axis K, K_2 from C, B, A, and D, and draw LQ the thickness of the wall at the springing line at C. Draw LM at right angles to the axis, and set off MN the difference between the thickness of the wall at L and M. Set NL at 10 degrees off the line NT (drawn parallel to LM), and draw LO at right angles to LN. This will form the line of set back for the projection of the points on the battering face.

From C erect a perpendicular CP to the springing line, and draw CQ_1 at a slope of 1 in 3 from the vertical.

Project lines parallel with the springing through all the points of the voussoirs on to CQ_1 through CP. The various distances from CP to CQ_1, transferred to LO, will give, by means of lines drawn through these points and parallel to LN, the positions of the joints and planes of the several arch stones. Similar lines projected parallel to K, K_1, etc., will at their points of contact with the former define the edge of the arch in front. Transfer the points to N_1R_1 of the section, and from a centre whose horizontal distance from R_1 is equal to the radius of the vault describe an arc upwards from R_1. This will be the boundary line for the back. Project the various members as before. The points of contact thus found transferred to the plan will give the points for the curve of the arch at the back.

To develop the surfaces of the voussoirs, take, for example, the keystone Hh gG. Draw a horizontal line hh, and from h erect a perpendicular hh_1 equal to hh_1 on plan.

Note.—The four-sided figure hh_1g_1g on plan gives the



A₁
1
g₁ f₁ e₁ d₁ c₁ b₁ a₁
O
D₁
A
D
2
3
E
C.
B
HALF PLAN LOOKING UP.
HALF PLAN LOOKING DOWN
BED MOLD
FACE MOLD
STONE 1
STONE 2
STONE 3
KEYSTONE

FIG. 120.

true mould of the top of the keystone, as Hh_2g_2G gives that of the intrados. The figure hh_1g_1g, reversed as in the projection, with its point h in contact with the horizontal line hh, forms the first plane of development.

Draw a line through h on plan parallel to h_1g_1, and with this as base line lay off distances on the horizontal, hh equal to the distance of the points of the voussoir from the line through h on plan. The true widths of

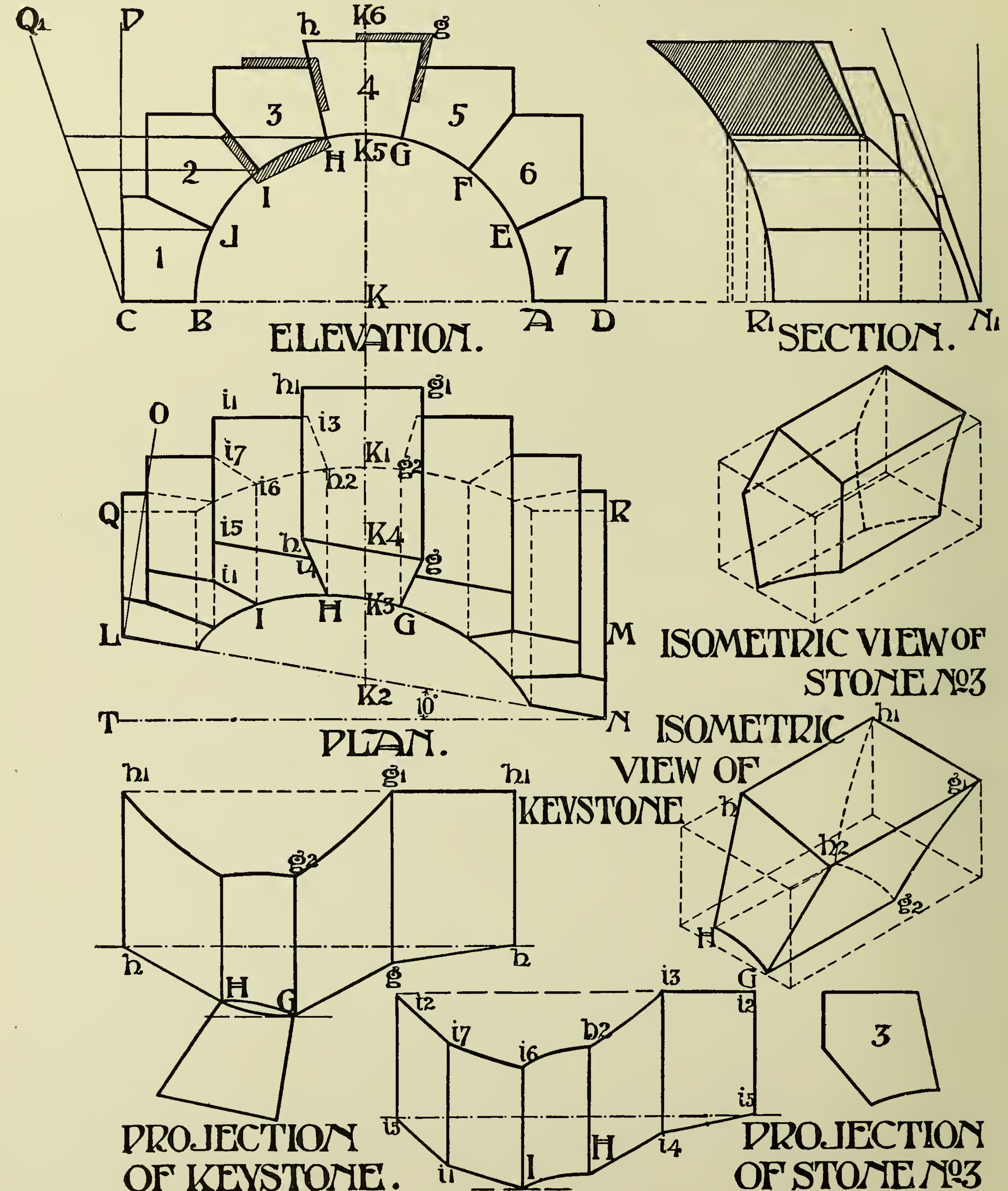


FIG. 121.

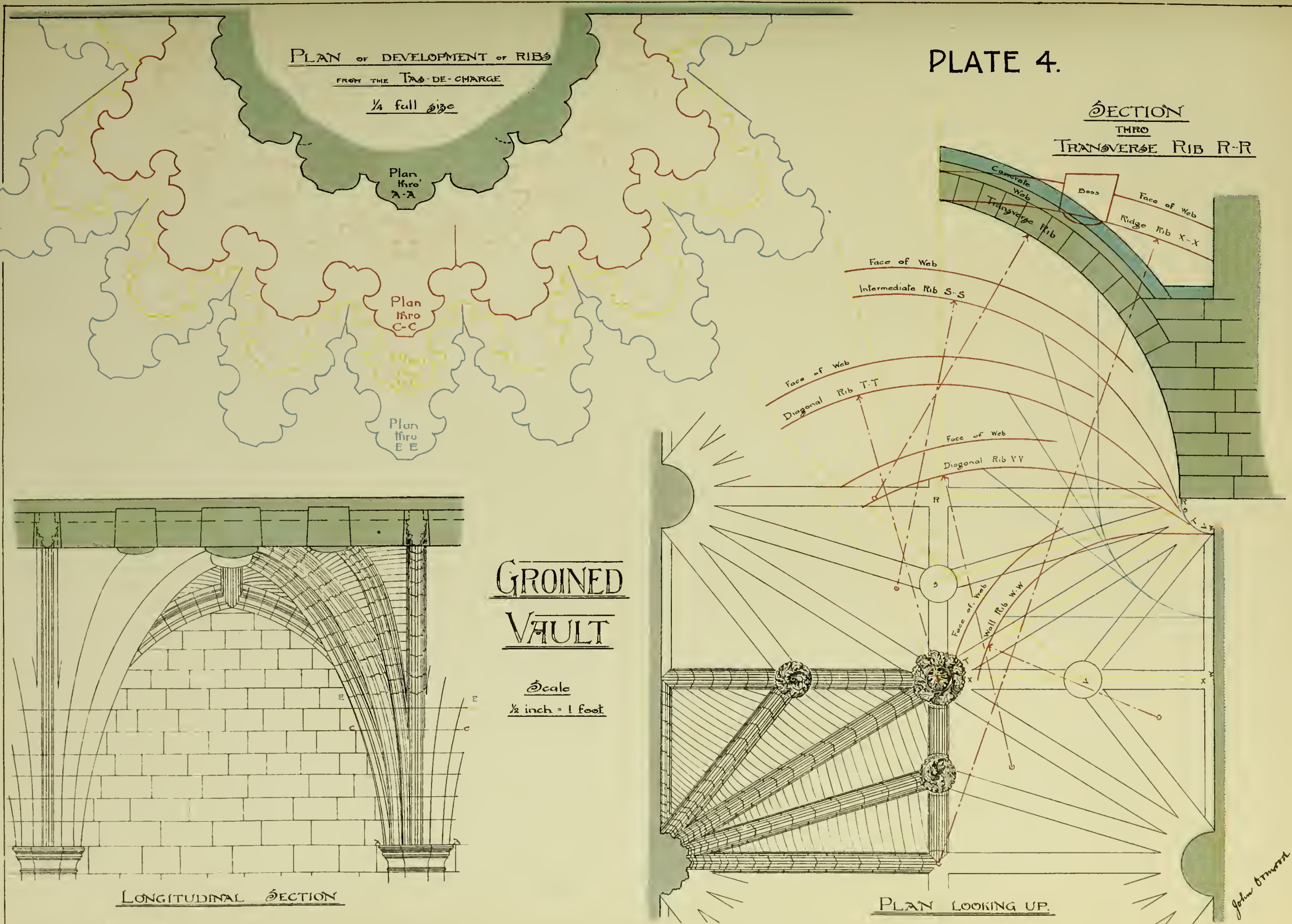


PLATE 4.
PLAN OF DEVELOPMENT OF RIBS
FROM THE TAS-DE-CHARGE
¼ full size
Plan thro' A-A
Plan thro C-C
Plan thro E E
SECTION THRO TRANSVERSE RIB R-R
Concrete
Web
Transverse Rib
Boss
Face of Web
Ridge Rib X-X
Face of Web
Intermediate Rib S-S
Face of Web
Diagonal Rib T-T
Face of Web
Diagonal Rib V V
Face of Web
Wall Rib W-W
GROINED VAULT
Scale
½ inch = 1 foot
LONGITUDINAL SECTION
PLAN LOOKING UP.
John Ormrod

the surfaces, as at gg_1g_2G, can be taken from the elevation, the other faces being treated in a similar way.

The developed figure with its sides revolved on the joints Hh_2, Gg_2, and gg_1 (see Plan) will then form the voussoir or keystone.

An isometrical projection of the keystone is also shown, with the enclosing squared block indicated by dotted lines. Another voussoir is shown both developed and in isometrical projection.

It should be borne in mind that in using bevels for the curves of the intrados great care should be exercised to apply them at right angles to the true axial line of the arch.

CHAPTER X

POINTED OR GOTHIC VAULTS

(*Contributed by* WALTER HOOKER)

THE term "pointed" is applied to vaults in which the surfaces rise to a point at the apex. They are called equilateral, drop, four-centred, etc., according to the method by which the section is set out, as explained in connection with pointed arches in Chapter VII. Pointed vaults are also termed Gothic vaults, as this form of vault is the fundamental structural form of Gothic architecture.

The simplest form of pointed vault is a continuous pointed tunnel, and ancient examples of this form exist in the Channel Islands and south-west France, but it is a form which is very rarely used in modern work, owing to the continuous thrust that such a vault exerts upon the walls. It should be noted that the primary object of Gothic vaulting is to concentrate the load upon certain points, which are made of sufficient strength to resist the thrusts; and to achieve this object the whole vault is supported upon a series of arched ribs, as shown in Fig. 122 and Plate IV. The spaces between the ribs, known as *Severies*, are composed of comparatively small stones, arched from rib to rib, thus bringing the centre load on the vault down to the ribs, and concentrating it upon the four corner supports. The masonry between the ribs is also called *infilling* or *panelling*, and work of this nature is often spoken of as *rib and panel work*. The courses of the infilling are usually, in English practice, made at right angles to the line bisecting the angle between the adjacent vault ribs at their springing. According to French practice, they are parallel with the ridge rib or joint.

It is interesting and instructive to note that in Renaissance vaulting the groins were made subsidiary to the vaulting surfaces, while in Gothic work the reverse is the case.

The English method of coursing the infilling (see Fig. 122) throws the joints out of winding at the vertices, and to make good the deficiency diagonal stones, forming serrated edges or toothing, are introduced to complete the vaulting. These engage with the courses of the panel stones and render the fabric homogeneous and stable.

The diagonal ribs (presuming the vertical arches to be formed of arcs of circles) will be elongated and flattened.

Fig. 122 shows how the simplest form of Gothic vault is set out, ABDC being the plan of a square compartment. The ribs in this case comprise:—

1st. The wall or longitudinal ribs or ribs against the side wall of the compartment, as at BD. These govern the curvature of the vaulting in a great measure, as on them depends the height of the arch above the springing.

2nd. Transverse ribs, or ribs running transversely across the opening, as AB and CD.

3rd. The diagonal ribs AD and BC.

It is customary to set out the curves of the wall or transverse ribs first.

In this case it is also presumed that the apices of all the ribs are in a horizontal plane, so that the radii of the diagonal ribs will require to be proportionally less than that of the transverse or wall ribs in order to bring their apices at the same height and keep a similar curve; and all the centres must be upon the springing line.

In this example, the compartment being square, the curves of the wall and transverse ribs are struck with the same radius. The diagonal rib is struck from two centres, the lower arc being struck with the same radius as the wall and transverse ribs, whilst the upper arc is struck from a centre within the radius of the former and on a line at right angles with the tangent to the curves at their point of junction. The variation of curvature in the diagonal rib should occur where it becomes entirely clear of the transverse and wall ribs. This can be so arranged that the apices of the two ribs are of the same height from the springing.

The feet of the ribs on the springing line now require to be adjusted.

If there is a cap forming the base of the ribs, its spread or abacus will form the seat of the members of the ribs, and the faces of the mouldings should be so adjusted as to evenly separate as they rise above the springing line. In the present case the outer members of the ribs are adjusted to form a neat regular figure, as shown on plan.

Elevations of half the wall and half the diagonal rib are now drawn showing the nosing line and the thickness of the infilling (see Fig. 122).

The first few courses are always worked with horizontal beds, and it is not until the ribs begin to clear each other that the beds are made radiating from the centres from which the arcs are struck.

This "tas de charge," as it is called, enables the walling to be continued and the roof covering put above

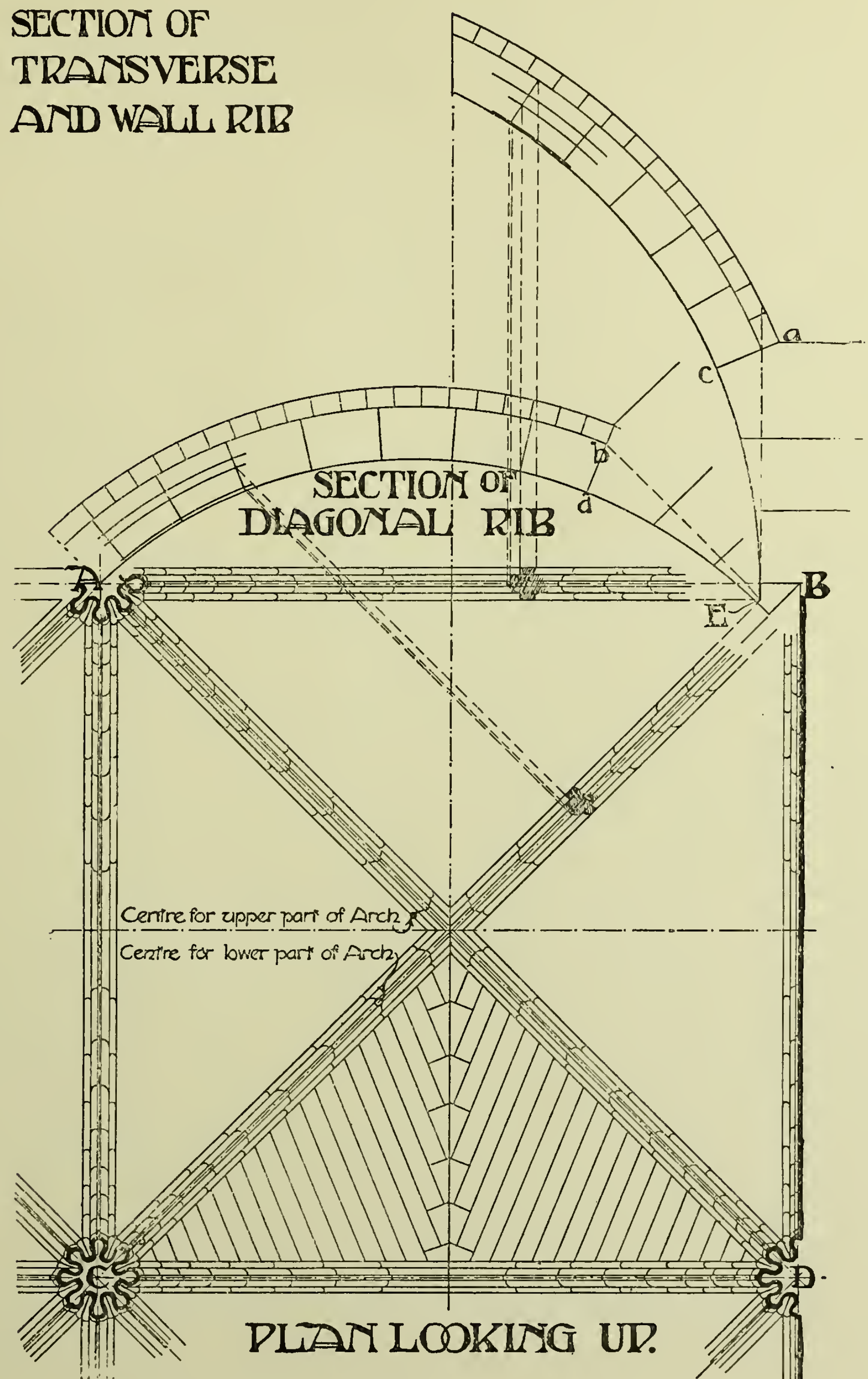


Fig. 122.

it, and for the vaulting to be added later under cover when settlement has ceased.

The point of clearance is found by erecting a perpendicular from the point of contact E of the outer faces of two adjacent ribs on plan until it cuts the upper outer edge of the rib in question on the elevation. See dotted lines Ea and Eb.

At these points a and b the upper beds are worked

into inclined planes at right angles to the several ribs which spring therefrom, as at *ac* and *bd*.

The springers are worked from a stone of dimensions sufficient to contain the ribs at the springing line, together with sufficient material for bonding into the wall, as shown in its plan on Fig. 123.

The top and bottom joints present no difficulty, as they are horizontal and parallel. Having brought these to a surface, mark off by means of templates the moulding on the bottom bed and the spread due to the rise on the top bed. The templates for stone No. 1 and No. 3 are shown in Fig. 123. It will be seen that the top bed mould for stone No. 1 forms the bottom bed mould for stone No. 2, and the bottom bed mould for stone No. 3 forms the top bed mould for stone No. 2. It should be noted also that, save in the case of the bottom bed mould, the sections of the mouldings as shown upon the bed moulds are not the same as those shown in the section of the ribs, but the former are projections of the latter (which have their true section along radial planes cutting the curves of the ribs) upon the horizontal planes of the joints.

The position of the curve of each rib is found and marked on the stone, and templates cut to the curve are applied to the nosing of the stones to which the faces are worked. The mouldings are then cut into the marks on the top and bottom beds.

The intermediate stones present no difficulty, as they are simple sections of each rib with the beds cut to bevels radiating from the several centres of the arcs or curves (as the case may be) from which the ribs spring. The backs of the stones are rebated to form a key for the panelling or vaulting surface between the ribs.

The keystones usually require somewhat different treatment, as the junction of the ribs being on different planes the mouldings do not mitre correctly. It is usual in this case to form the keystone as a boss or carved projection, and to let the ribs disappear behind the carving.

In the present instance, as the ribs intersect at right angles, mitres could be applied with propriety, a plan of the key being shown (see Fig. 123) together with an elevation giving the bevel of the joints and the face of one of the joints with the moulding of the rib in section. The dotted lines indicate the outline of the squared stone before the operation of cutting is proceeded with. The face of the joints would be worked first by means of proper bevels raking from the squared surface of operation.

In all cases the joints are worked to a plane surface first, and to the true rake ; and on each joint the section of the moulds is punched in on the faces thus formed by the aid of zinc templates accurately cut to shape.

The stone is then worked to the mouldings back towards their intersection or mitre line, and the raking bevels are applied to give the curve to the face of the moulds. The top of the stone can follow the same bevel or may be left square, the rebates as shown being used to key the panel stones.

In the case of the panels, the work is built in regular courses at right angles to a line bisecting the angle formed by two adjacent ribs on plan. The surface is slightly concave, thus forming a flat arch. Where two of these vaulting surfaces unite, the stones along the groin line are formed as shown in the section of rib in Fig. 123, in order to bond with the coursing. In this case no rib is projected on the groin line. The joints of the panelling frequently present a twist when seen from below. This is termed "ploughshare" coursing, from its fancied resemblance to that implement, and is employed to render the thrust on the panel units even and within the limits of stability.

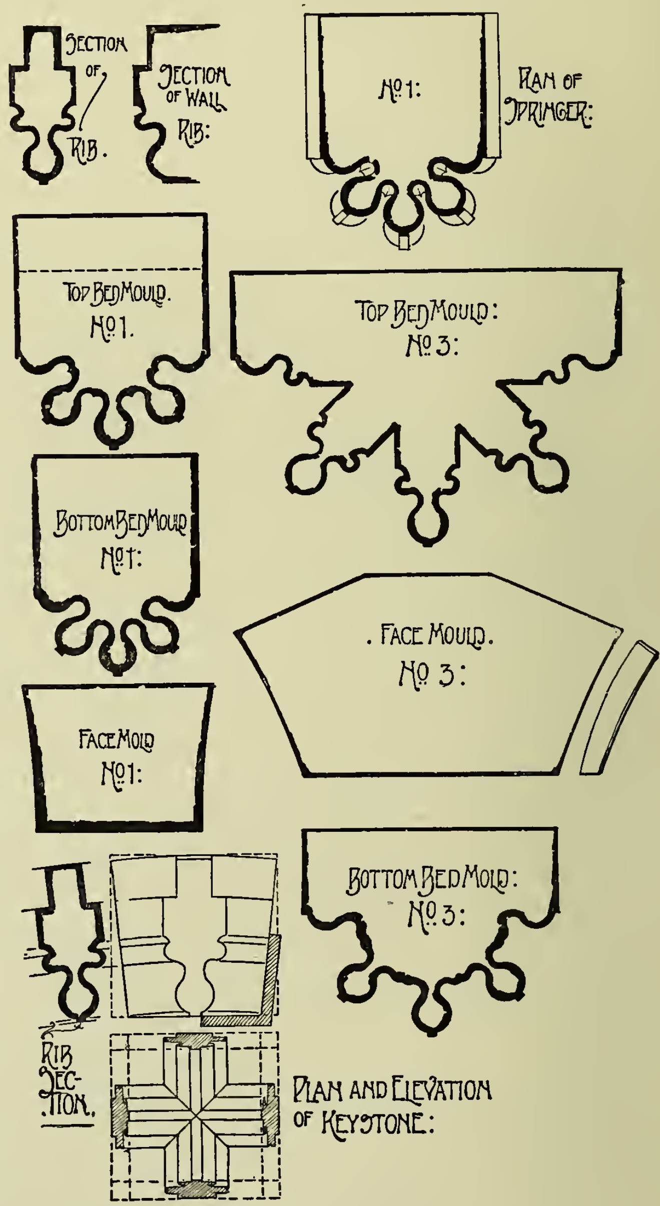


Fig. 123.

Reference has been made to cases wherein ribs,

not meeting at the apex at right angles (such as in cases where the vaulting surfaces are not square but oblong) the intersection of the mouldings would not form true mitres. In these cases the defect, as just said, is hidden by employing carved bosses, projecting from the keystones in such a manner as to absorb the mouldings, which die into the carvings without contact with each other.

To set the keystone out with its boss proceed as follows.

Lay out a template with one edge square and the other laid off to the curve of the diagonal ribs. From the square edge lay off a line perpendicular to it, forming the axis of intersection of the various ribs. Set out similar templates, with the curves of the other ribs forming the junction at the key, and with square edges as before; and lay off adjacent to the perpendicular line the portion of the boss that would be required to cover the mitre were it to be carried through. Cut away the stone to the curve of the template for the main rib, and proceed with the intermediates by applying their several templates at their true angles with the surface thus formed, and cutting down until the faces are out of winding. The surfaces will then show the curves of the ribs on the soffit, the stone for the boss carving being left for the final operation. The remaining part of the work is proceeded with similarly to that described for the ordinary rib stones. The joints will, of course, be formed at right angles to the curve of the ribs with which they are designed to engage.

Plate IV. the work of Mr. John Ormrod, A.R.I.B.A., shows the plan, sections, and setting out, together with details of a continuous groined vault of more elaborate design than the one previously detailed.

In this case it will be seen that ridge ribs and intermediates are introduced in addition to the transverse and diagonal ribs. Another feature may be noticed in that the height of the wall ribs is lower than the diagonals and transversals. This admits of a certain amount of rise in the ridge rib connecting the apices of the wall and the diagonal ribs, and may be considered as adding both to the beauty and stability of the general vaulting.

An enlarged plan of the ribs at their junction on the springing line, together with outlines of the mouldings at different levels, serves to show the gradual clearance of the members of the mouldings on the ribs, until, at EE, their final severance each from the other is completed and the panelling between them emerges from the mouldings.

The sections of the rib faces are clearly shown by the dotted lines over the plan, with the points of departure from the springing line and the centres from which they are struck.

The wall ribs in this instance are stilted.

As the transverse ribs more frequently govern the general characteristics of the structure in this type of vaulting it is usual to set these out first. The height of the vault being fixed, the ribs may be struck either as one or two centred arcs. In this instance it is one centred, but with the centre well beyond the half of the span, to give a well pointed arch.

The next point is to settle the diagonals. The radius should be as nearly as possible similar to that of the transverse and the centres on the springing line of the vaulting. The vertical height being set out by drawing a perpendicular to the centre of the diagonal on plan, and marking off the vertical height of the transverse ribs, an arc with the centre of the boss and distance equal to the height will give the curve of the diagonal. The intermediates are obtained by a similar method as respects those engaging the longitudinal ridge. The cross ridges (from the apex of the wall ribs to the boss at the junction of the diagonals) are curved, and are governed by the difference in the height of the apex of the wall ribs and that of the junction of the diagonals were they allowed to meet (presuming the boss to be removed). This is set out in cross section, and a centre found that will give a flat cambered arch suitable to the difference of vertical height between the two points.

The intermediate rib VV can be set out from this as respects its height, as the position of the point of junction between this and the cross ridges at the centre of the boss is shown in the curve of the cross ridge already laid down, and its springing line is common to the other ribs.

It should be further borne in mind that, with reference to the primary ribs more especially, but also with all the ribs, it is necessary that the separation of the members of the mouldings and of the disengagement of the ribs as a whole should be effected as nearly as possible at a uniform level. To effect this, commencement may be in this instance made with the transverse rib, which presents no difficulty, as a simple segment of a circle suffices to define its outline. The diagonals, however, should be set out as far as the line of severance of the ribs on plan by a vertical line, such as E*a* or E*b*, as shown on Fig. 122, the joint being shown here as a radiation from the centre of the curve forming the soffit line of the transverse rib. The projection is therefore a fixed dimension up to this joint for all the ribs.

It will be seen by a reference to the plan that the diagonal has a greater projection from springing to apex than the transverse rib. It results therefore that an arc will have to be found that will be tangential to that from the springing to the joint face, and that will touch the apex height at the point of contact of the diagonals.

This can be done by means of the methods set out in Chapter VI.

The system of arranging the joints and the moulds and templates required for the various stones has already been described.

The bosses, however, merit a further description. Take, for example, the centre boss, which forms the junction of the diagonals and ridge ribs, and is therefore a stone having 8 joints or stumps to engage with the 4 diagonals and 4 ends of the ridge ribs.

The bed mould is simply a replica of the stone on the plan, with the adjoining stone work removed, as shown in Fig. 124.

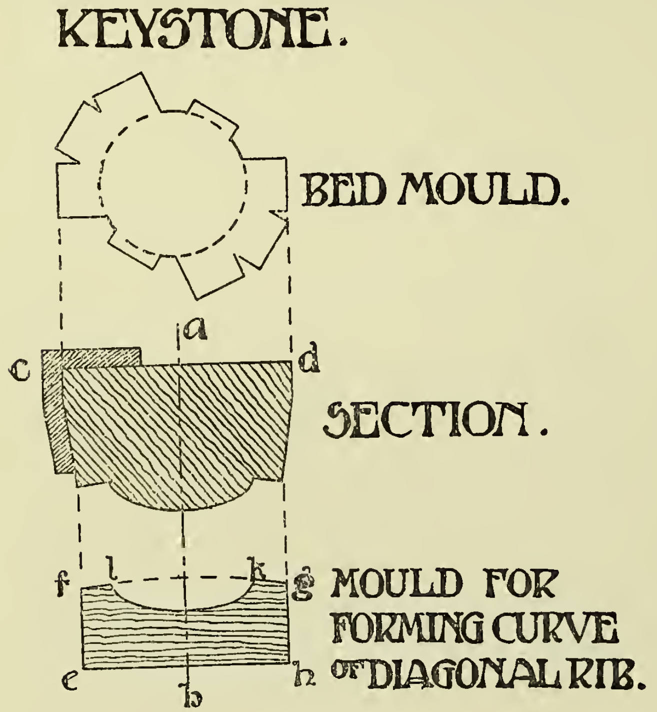


FIG. 124.

skewbacks for the adjacent stones of the ridge ribs, as shown in Fig. 125 and in Plate IV. By this means additional stability is given to the apex stone. A section through the diagonals, and giving the radiating joints, appears in Fig. 124.

The bevels are applied from the surface of operation, as *cd*, which is at right angles to *ab*, the centre of the stone and the axis thereof. The moulds are used only to obtain the curves of the ribs, as their direct application is not practicable.

The bed mould is scribed on the surface *cd*, and the direction of the ribs from the common centre thus accurately gauged.

The radiating joints of the diagonals are next ascertained, and the cross sections of the rib moulds scribed on the ends both of the diagonals and the ridges. These are worked up to the boss, and the curves worked in, the ridge ribs being cut back to the skewback as required.

The bosses are generally carved, as is shown in Plate IV., either with a conventional design of foliage or with monograms or heraldic devices ; but this work is usually left until the stone has been placed *in situ*, to avoid injury to the finished work in fixing it in position.

To more clearly illustrate the method of applying templates to the centre stones as above described, a simple example is taken. The mould is shown at *efgh* in Fig. 124, the arc *fg* being struck from centres corresponding with the centres of the arcs of the circles of the ribs required. This is the mould for the curve of the diagonal rib, its base being at right angles to the vertical or axial line. By revolving the mould around the line *ab* into the positions shown on plan, the curves of the other diagonals are ascertained.

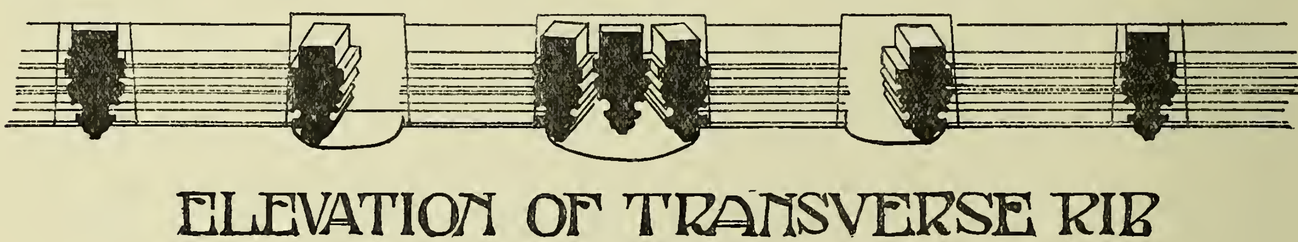


FIG. 125.

The sections are more complicated, and it is better to arrange the joints in such a manner that those of the diagonals are struck from the respective centres of the curves of the ribs. The ridges are better cut in reverse, and either rebate jointed or made to form

The template for the curve of the ridge rib is also found and used in the same way.

The curve *kl* represents the boss, and would be cut out from the mould, and the corresponding stone left on the key.

CHAPTER XI

DOMES

(*Contributed by* WALTER HOOKER)

THE full-page drawing, Plate V., gives the general drawings with constructional details of a small Mausoleum in stone, designed by Mr. E. L. Hampshire, A.R.I.B.A.

The general scheme will be seen to embrace a severe Classic chamber, with a vault below, and porticoes on each of the four façades, approached by flights of steps in concentric semicircles.

The main principles involve the application of a domical roof over a four-sided chamber, with the angles curtailed by splays with salient rings over, forming pendentives.

The chamber measures 24 feet square from the main walls, and the diameter of the dome is of the same dimension.

The walls are necessarily of massive design, to resist the thrust of the heavy masonry in the dome. These are further strengthened by the porticoes, and the stability is increased by the weight of the pediments on each façade.

The inner curve of the dome is struck from a centre on a line with the under side of the cornice, and in section is a semicircle.

The weight of the dome is minimised and economy studied by reducing the thickness of the dome at the apex and increasing it at the haunches and springing line.

The centre for the outer arc of the dome is found, therefore, somewhat below that of the inner or intradosal arc.

The setting out for the stones of the vertical walls, columns, and their entasis, pediments, etc. needs no further comment, as general details of the method usually employed are given elsewhere in this volume.

The pendentives and dome, however, require more particular attention.

It will be seen that the pendentives are generated from a plane surface oversailing in a curve vertically to meet the periphery of the dome.

To set out the stones—lay out on a plane surface or even floor the plan of the wall at the springing line of the pendentive, which is a right angle formed by the two main walls, having the entering angle splayed at an angle of 135 degrees with each face, as shown in Fig. 126.

From C, the centre of the circumference of the dome at the springing line, and at 12 feet distance from the wall faces, draw a circle tangentially to the same. This will give the projection of the pendentive.

The vertical curve is found by setting out the projection from the wall face and the height at any convenient point, and proceeding in the usual way when a centre is to be found, *i.e.* by means of arcs dividing the chords. A line drawn through the points of contact of the arcs will contain the centre of the curve of the pendentive. This also is shown in Fig. 126.

In setting out the joints, which are shown in Fig. 126 asplane surfaces and not as joggles as in Plate V., each should be struck to the radius of the circle on plan, while the beds are commonly set out horizontally, though it is permissible to radiate them from the centre of the vertical curve.

All stones should break-joint. Any one stone can now be set out by a reference to the plan and section. (Fig. 126). An isometric view of stone A on plan is shown in Fig. 126.

The method of bringing the stone to the finished shape has already been described.

The particular bevels required in this instance are obtained by reference to the plan, and additional bevels are taken from the arcs of the pendentive, both horizontal and vertical. There is one feature worthy of note respecting the obtuse angle at the base of the stone dying into the curves of the upper portion. The joggles present no difficulty, provided that care be taken to allow sufficient stone for the salient joggle when sawing out of the rough.

A similar system is applied to the setting out the stones of the dome. As these all have radiating beds and joints, one set of bevels will apply to nearly all the stones.

It may be noted that, as the horizontal and vertical beds and joints are in neither case square with the axis of the stones, the bevels will have to be made accordingly. This is illustrated in Fig. 127, showing the axial line of one of the stones, with the dotted lines representing the enclosing squared block. These stones can be prepared in pairs, the saw cut dividing them being utilised to form a bed or joint, as may be convenient, and thus save time and labour (see Fig. 128).

Isometric views are shown on Plate V. of various stones, with the method of joining and details of the application of secret joints and of the cornice mould,

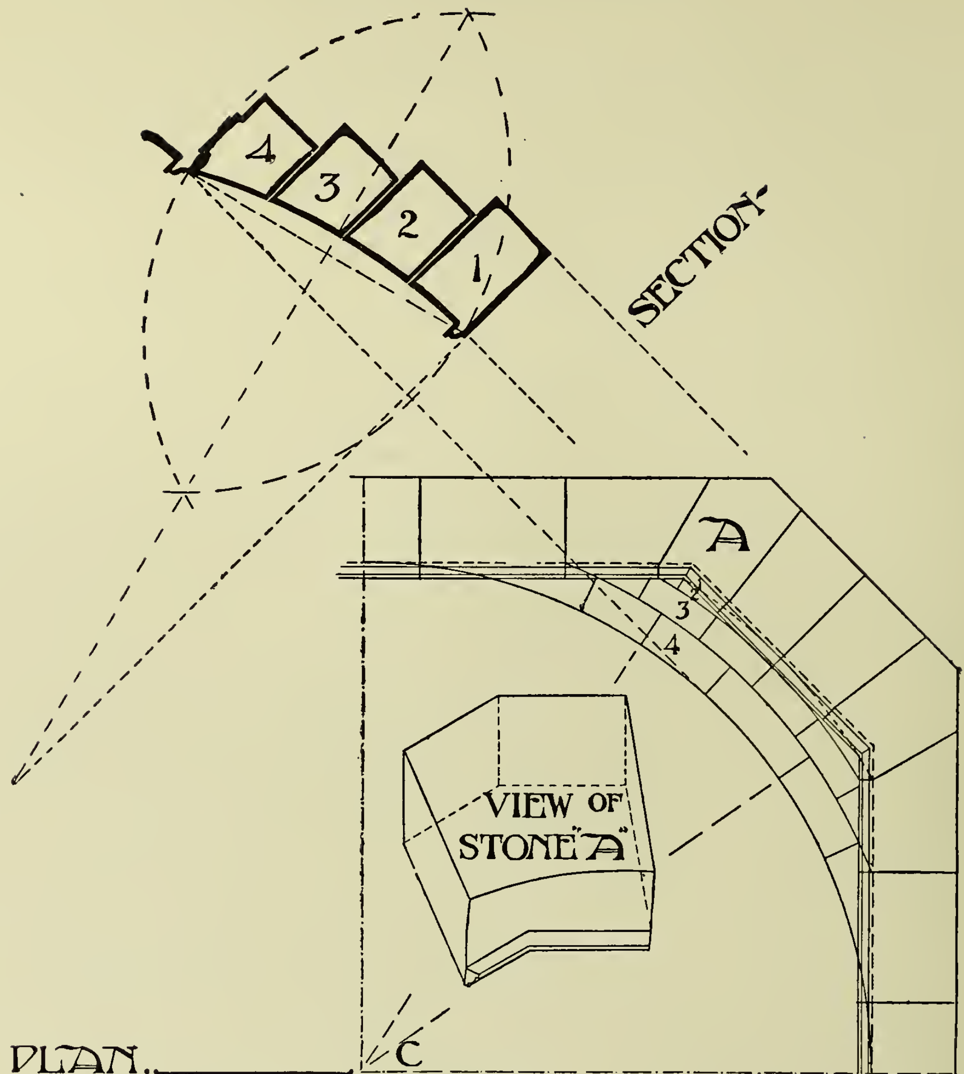


Fig. 126.

which are sufficiently explanatory of themselves to need no further comment.

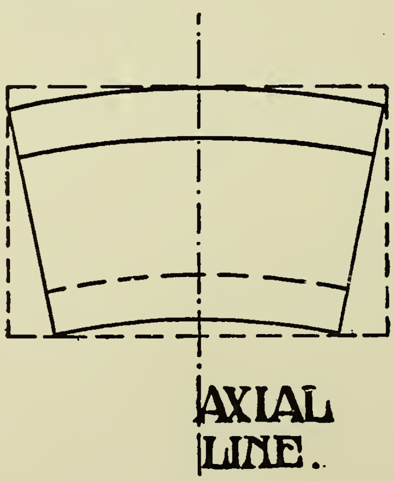


Fig. 127.

Figs. 129, 130, and 131 give the plans, section, and elevation of the central tower for a new dyehouse designed by Mr. A. W. S. Cross, F.R.I.B.A.

The plan is laid out on the basis of an octagon, with buttresses at the salient angles skilfully masked as columns supporting the well-proportioned cornice.

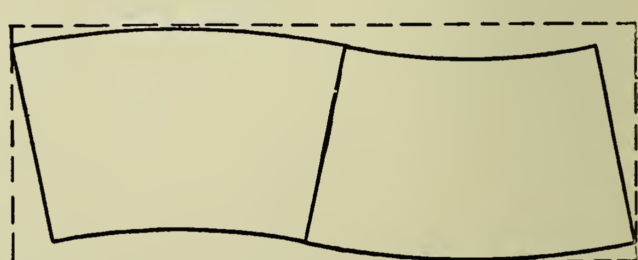


Fig. 128.

The lower portion is entirely of stone externally with brick backing.

Access is given to the main entrance by a flight of four broad steps of semicircular shape on plan, the

PLATE 5.

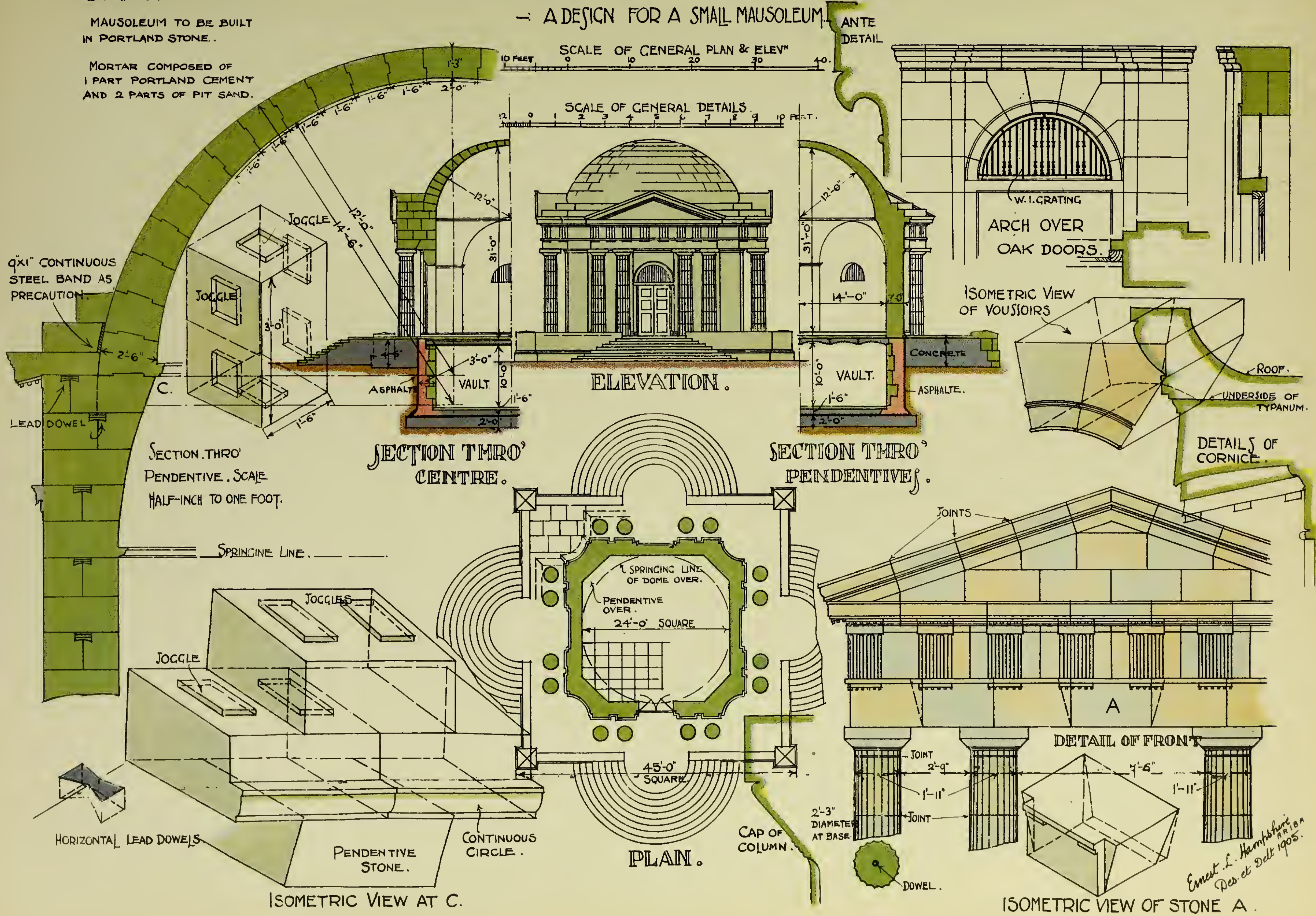
CONSTRUCTIVE MASONRY.

— A DESIGN FOR A SMALL MAUSOLEUM.

NOTE. ALL VOUSSOIRS LAID TO BREAK JOINT.

MAUSOLEUM TO BE BUILT IN PORTLAND STONE.

MORTAR COMPOSED OF 1 PART PORTLAND CEMENT AND 2 PARTS OF PIT SAND.



lowest of which is carried well outwards, the end cutting into the base with a flat sweep.

The pedestals of the columns are carried on a plinth mould at the floor line, the main portion being of ashlar with recessed joints running continuously between the pedestals and forming a regular base to the building.

The upper part of the pedestals is finished with a composed of two curves of contrary flexure, with a horizontal band at the junction, the angles abutting on the blocking course being finished with moulded consoles. The apex stone is surmounted by a moulded base carrying an ornamental metal finial.

The entrance is recessed between the pedestals of the front elevation, with a flat arch in one stone moulded on the edge and carrying a projecting tran-

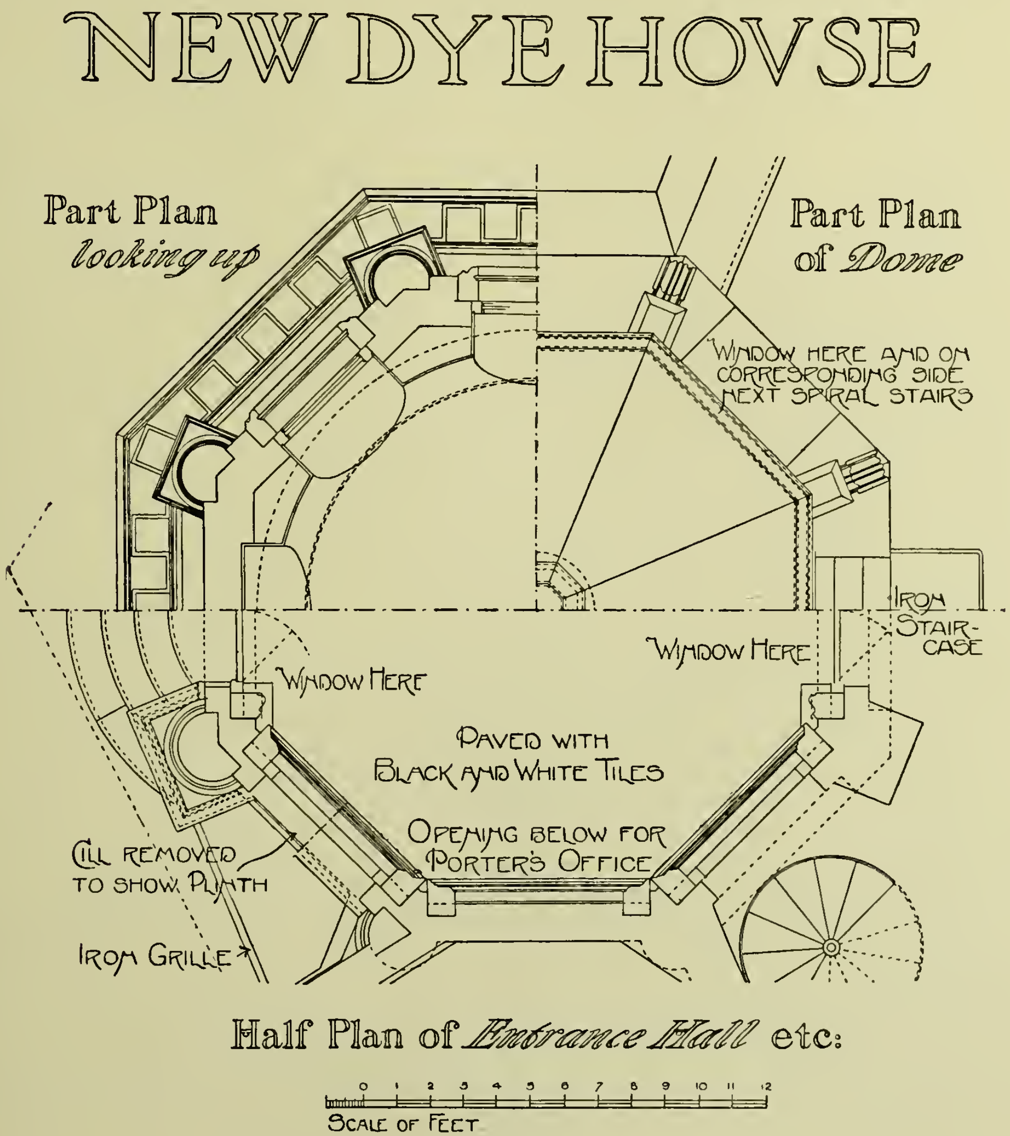


FIG. 129.

cornice mould of regular design, on which the bases of the columns rest.

The columns are of rounded section on the face, their backs being jointed with the brickwork of the main wall, and their lower portion interrupted with alternate squared stones and completed with a cap and neck mould. Over these a heavy entablature is supported, with architrave, frieze, and cornice, finished with a blocking course.

The whole is completed by an octagonal domed roof, some over, which also forms a sill for the window and constitutes a horizontal band with the adjacent walls. Light is provided by semicircular openings with alternate arch stones and brickwork, the stone voussoirs being salient.

Circular bullseye lights or lunettes are provided with moulded arch stones and keys at right angles to each other.

Respecting the individual portions of the stonework, such as the doors, windows, columns, entablature, etc.,

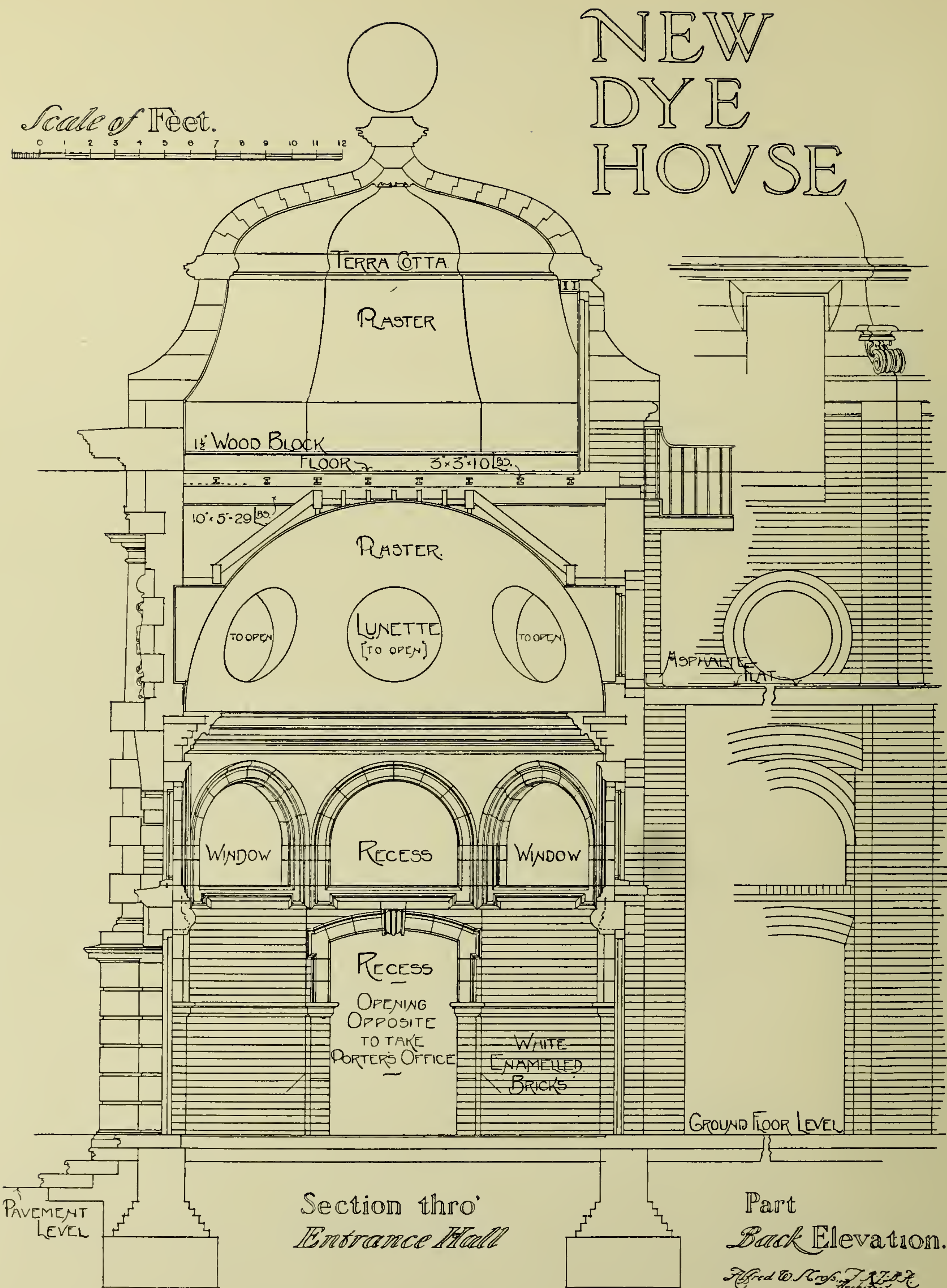

NEW DYE HOVSE
Scale of Feet.
0 1 2 3 4 5 6 7 8 9 10 11 12
TERRA COTTA
PLASTER
1½" WOOD BLOCK FLOOR
3"×3"×10 LBS.
10"×5"-29 LBS.
PLASTER
LUNETTE (TO OPEN)
TO OPEN
TO OPEN
ASPHALTE FLAT
WINDOW
RECESS
WINDOW
RECESS
OPENING OPPOSITE TO TAKE PORTER'S OFFICE
WHITE ENAMELLED BRICKS
GROUND FLOOR LEVEL
PAVEMENT LEVEL
Section thro' Entrance Hall
Part Back Elevation.
Alfred W. S. Cross. F.R.I.B.A. Architect

FIG. 130.

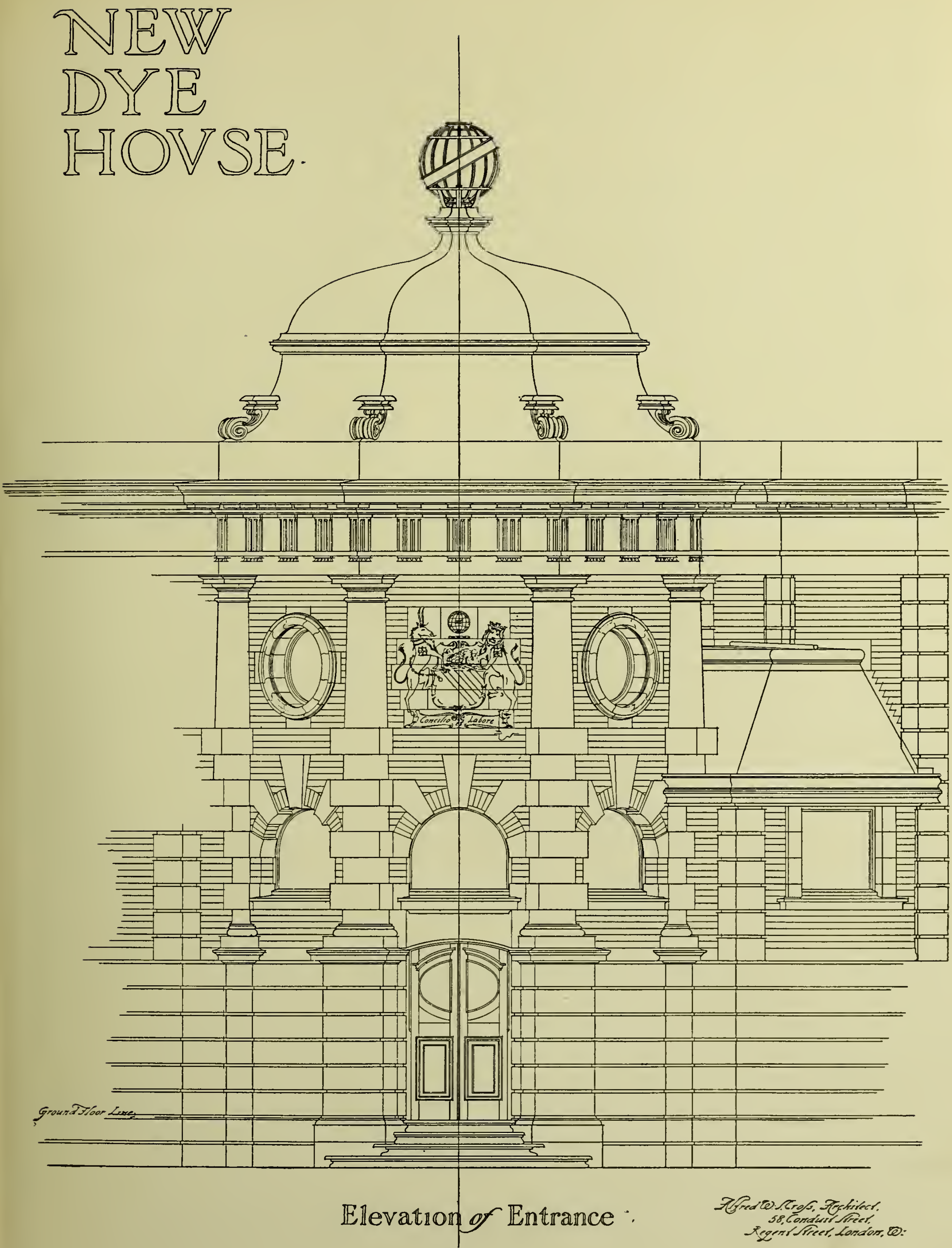

NEW DYE HOVSE.
Concilio et Labore
Ground Floor Line.
Elevation of Entrance.
Alfred W. S. Cross, Architect.
58, Conduit Street,
Regent Street, London, W.

FIG. 131.

sufficient detailed descriptions have been provided in other chapters for no further reference here to be needed. As regards the dome itself, this presents distinctive features which require some more precise description.

It will be seen that the lower half is shown with the joints horizontal, and that advantage has been taken of the design to give increased stability to the whole by widening the beds of the lower courses. It might be considered advisable to joggle one or two of the lowest of these, although, as the superincumbent weight is not excessive, this has not been considered absolutely necessary. On this lower section a complete course or band of terra-cotta has been inserted, which acts as a stop to the plaster face of the interior, and also, from the length of the pieces, would to some extent act as a tie to the structure.

Above this the voussoirs have been joggled to guard against opening out of any of the courses.

The method of setting out any individual stone has already been explained.

Stones have been inserted in the face of the wall over the main entrance with a carved coat of arms thereon. These are bosted out and left with sufficient projection to be finished by the carver when the building is nearing completion.

CHAPTER XII

STONE COLUMNS

(*Contributed by* *Walter Hooker*)

It is of the utmost importance in the preparation of the finished stone for its destined position in a building to ascertain with accuracy the exact sizes and shapes of a careful gauge of the brickwork that may either form an integral part of the facing, or may be used as a backing to the external skin of stonework.

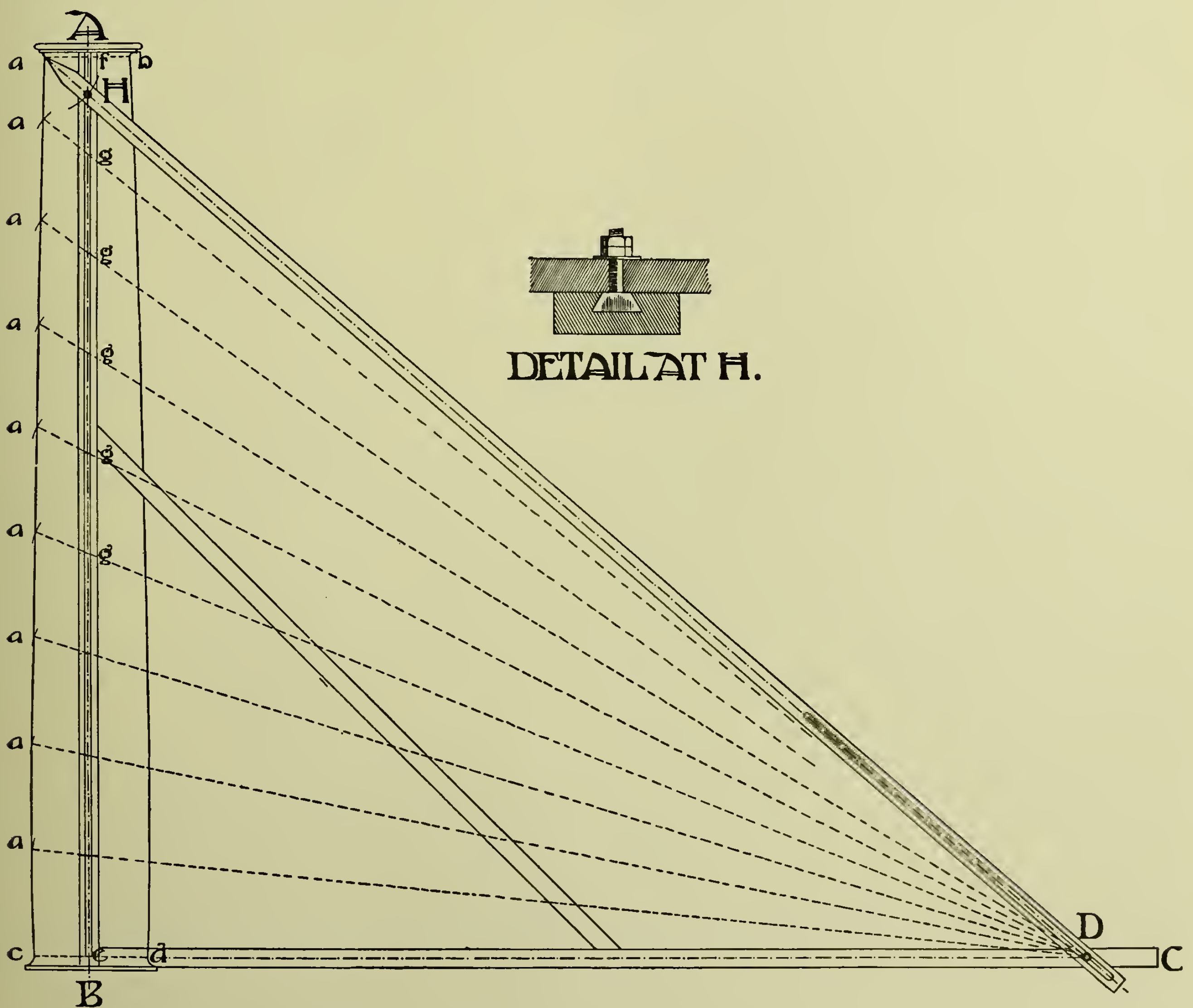


Fig. 132.

each of the various units that go to make up the finished whole.

To this end the mason requires to set out to full size the several stones, with allowance for joints, and also

The rough blocks can be ascertained by measurement from the full size setting out, and care should be exercised to ensure that they should exactly contain the extreme dimensions of the stones as they will be when

cut to their accurate shapes. The first process must embody the production of a plane surface; unless, as in the case of "free stones," the surface have already been sawn to a "face," which in this instance may only require a little labour to make it true and plane.

Columns with Entasis.—To set out a column with entasis on it, draw a line AB (Fig. 132) to represent the axis of the column, and make its length equal the required height of the column, and set out the top and bottom diameters *ab* and *cd*. From the point *e* which bisects the base *cd* draw *e*C indefinitely, and at right angles to BA. Bisect the top diameter at *f*, and divide *ef* into any number of equal parts, as in *g*, *g*, *g*, etc. With *a* as centre and *ce* as radius describe an arc cutting AB atH . Join *a*H and produce it to cut *e*C at D. From D draw lines through the divisional points *g*, *g*, *g*, etc. Then with the centres *g*, *g*, *g*, etc., and radius *ce*, describe arcs cutting the lines through D*g*, D*g* in the points *a*, *a*, *a*, etc. A curve drawn through the points *a*, *a*, *a*, etc., will give the line of the entasis, which can be drawn with a flexible piece of pine or thin steel. The curve is known as a conchoid, and is usually called the conchoid of Nicomedes—a famous geometrician who invented the practical method of setting out this curve, and lived in the age of the philosophers.

The practical method of setting out this curve is also shown in Fig. 135. Two straight edges AB and BC are jointed together to form a right angle at B, and strengthened by means of the strut. A dovetail groove is made in the straight edge AB, in which a sliding bolt is inserted as shown in the detail. A third straight-edge *a*D is pivoted to the bolt at H, and is slotted so as to slide along another bolt at D. If the end *a* of the straight-edge *a*D is pulled downwards it will mark out the required curve of the entasis. A pencil is fixed at the end in order to mark out the curve. If a suitable means be provided of fixing the pencil in various positions along *a*H, and for fixing the bolt at various positions along BC, and the slot in *a*D be made conveniently long, this apparatus can be used for columns of all sizes.

Another somewhat simple method, though giving a less graceful curve than the conchoid, is sometimes employed for setting out entasis on columns.

Draw the axis AB (Fig. 133) equal to the required height, and set out the upper and lower diameters *ab* and *cd* respectively. Make BC equal to one-fourth of the height between *ab* and *cd*. Through C draw a line DE at right angles to the axis AB. From *c* and *d* draw lines parallel to the axis and cutting the horizontal line through C at D and E. Describe the semicircle DFE, and project *a* and *b* on to its circumference at a_1 and b_1. Divide CA into any number of equal parts, in this case four, and divide the arcs a_1 D and b_1E into the same number of equal parts. From each of these divisional points in the arcs erect perpendiculars to cut

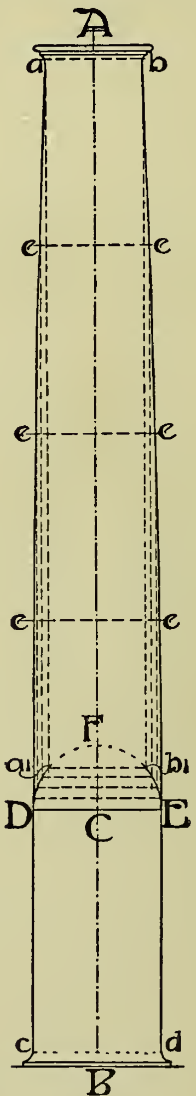


FIG. 133.

the horizontal lines through the divisional points of CA in *e*, *e*, *e*, etc. Lines drawn through D *e e e a* and E *e e e b* give the finished curves of the entasis.

Sometimes the entasis is curved to part of a hyperbola or other curve. It is better in such a case for the architect to give a table of the offsets of this curve from a straight line, from which a mould can be constructed.

CHAPTER XIII

STONE STAIRS

(*Contributed by* WALTER HOOKER)

THE technical terms used in connection with stairs, and the methods of proportioning the risers to the treads, and of setting out stairs, are explained in Chapter VI. Part III. of Volume II.

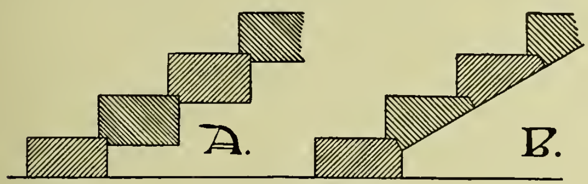


FIG. 134.

The fliers of plain stairs are usually worked with the soffits parallel to the treads, in section presenting a series of rectangles as shown at A, Fig. 134. In more important work, and where the soffits are visible, they are splayed as at B, forming winding surfaces on the under side, whence they are termed "spandrel steps."

With staircases where no winders are used the fliers rise to quarter or half-landings, and a section of the stairs will show a raking surface when splayed on the under side, forming a continuous line parallel to the line of nosings. Where winders are used the soffits of the winders will have twisted surfaces or curves in section, and will require a series of bevels accurately cut to suit them. The soffit of each winder will flatten out as it recedes from the centre, owing to the greater width of the steps as they approach the outer wall of the staircase. A portion of stone of square section is left on to form a bed in the wall.

Fig. 135 shows an example of a turret stair. Here the well is circular on plan. It is assumed here that the height from floor to floor is 12 feet, while the diameter of the well is 5 feet 6 inches. Each step is made of one solid stone, with a circular piece left on the smaller end, which forms, when the stair is built up, a continuous central newel. The first operation in setting out full-size working drawings is to determine the rise and, tread of the steps. In this case the total height from floor to floor is divided into 24 equal parts, making the risers each 6 inches deep, while the circumference of the turret is divided into 15 parts, thus giving a comfortable tread as well as providing ample headroom. This headroom should not be less than 6 feet 6 inches, and where possible it should be more. In small turrets, however, it is not possible to give the steps a comfortable rise and tread as well as an ample headroom, and a compromise should be made with due regard to all three factors. In Fig. 135 the entire plan and elevation of the stair is shown, but in practice it is only necessary to calculate graphically or mathematically the exact sizes of one step, as each is the exact counterpart of the next.

When the steps are simply rectangular on plan the rise and the back face of the steps are made tangential to the central newel, as shown on the separate "Plan showing Tangential Steps" (Fig. 135), on which the back of step No. 1 is shown in dotted lines. This saves labour, and makes the step stronger at the smaller end.

To set out one step on plan, divide up the circumference of the turrets into the required number of equal parts, and draw lines radiating from the centre of the turret to each of these points as shown dotted on steps Nos. 1 and 6. These dotted lines represent the positions of the several risers. Draw a circle to represent the central newel. Then draw on the nose and the part beneath the adjoining step. These are drawn respectively parallel to the riser lines of the stone itself and the stone above it. The wider ends of the steps are built into the wall. The bed mould for each step is shown shaded on step No. 10. The under surfaces of the steps are splayed, thus forming a continuous spiral, intersecting the walls and the central reveal in spiral lines as shown upon the elevation.

In setting out individual steps upon the stone a zinc template is formed of the shape of the shaded step in Fig. 135, or two laths are nailed together with cross pieces, giving the angle of divergence from the parallel, and gauging the extra width of the wall end from the well hole end, as is shown in the lowest drawing on the right-hand side of Fig. 135.

Another detail of this figure shows the soffit of one step, the stone being turned upside down, and illustrates the twisting surface required to form the soffit when built up into a spiral plane.

To set out the twist, divide the two ends into the same number of equal parts. By working drafts down from the square section, from *a* to *a*, *b* to *b*, etc., and of equal depth from the square face, the soffit face will be reached. The intermediate surface can then be brought down to the same plane, and will give the finished soffit as shown.

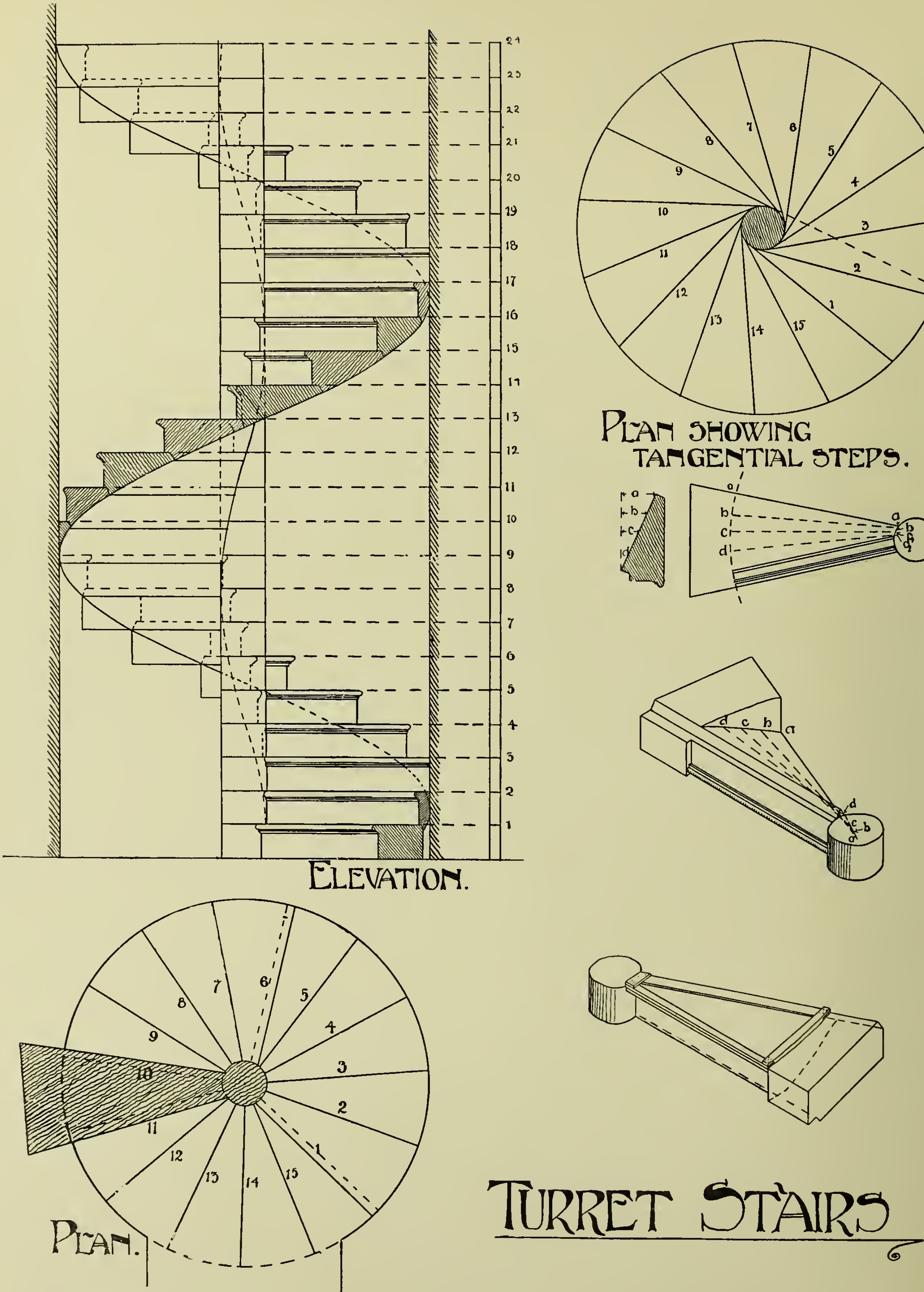

ELEVATION.
PLAN.
PLAN SHOWING TANGENTIAL STEPS.
TURRET STAIRS

FIG. 135.

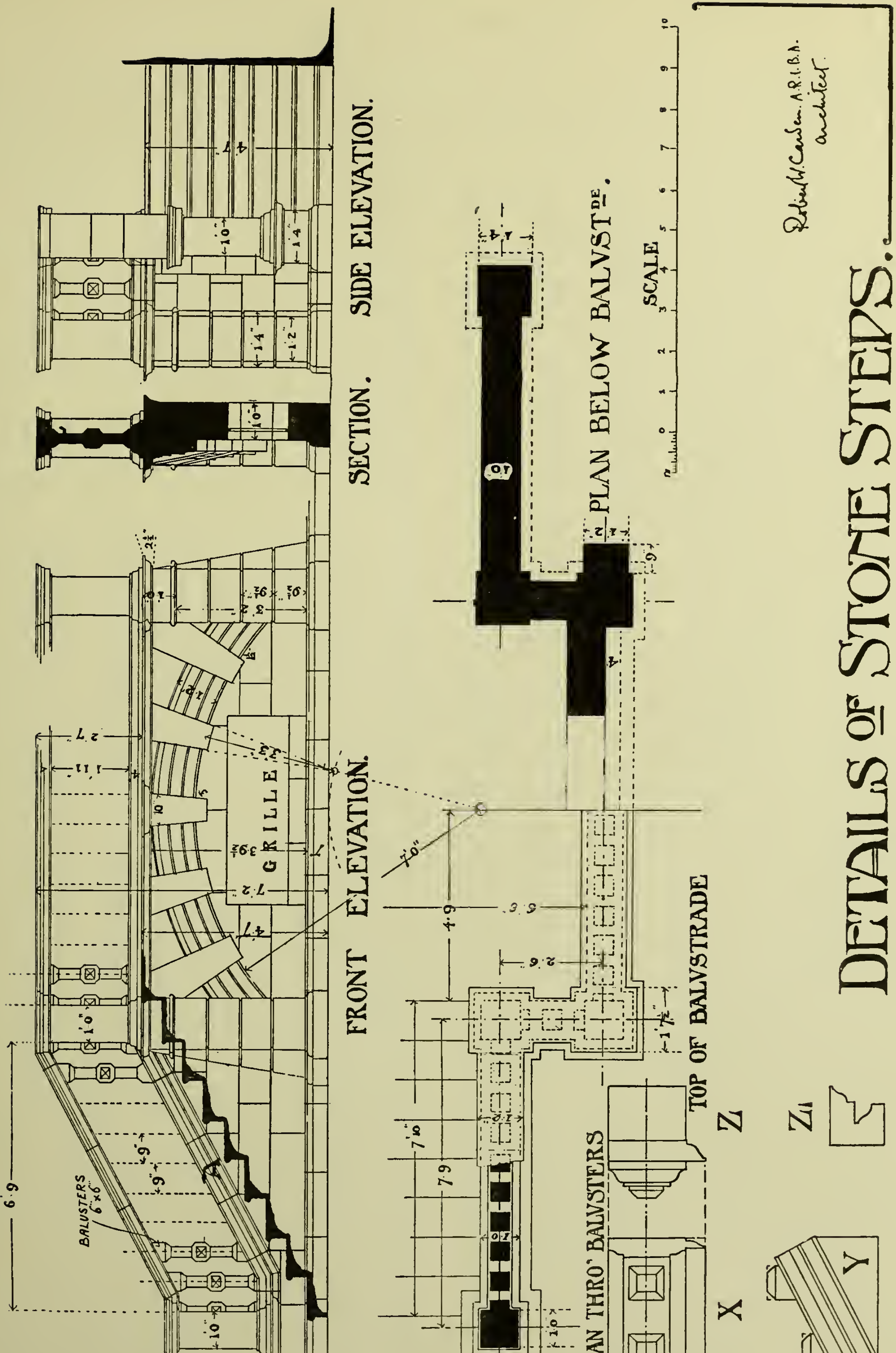

DETAILS OF STONE STEPS.
FRONT ELEVATION.
SECTION.
SIDE ELEVATION.
GRILLE
BALUSTERS 6"x6"
PLAN BELOW BALUSTRADE.
SCALE
PLAN THRO' BALUSTERS
TOP OF BALUSTRADE
X
Y
Z
Z1
Robert W. Carden A.R.I.B.A. architect

Fig. 136.

The square portion left on at the end is built into the outer wall. The winders for connecting two straight flights are treated in the same manner, moulds for the outer ends being formed by developing the elevation of the curved portion.

Fig. 136 represents the plan, elevations, and part section of a double flight of stone steps leading up to the entrance of a modern mansion designed by Mr. Robert W. Carden, A.R.I.B.A. A reference to the plan will show the steps so arranged that the two flights abut on a broad landing, which is further increased in area by a projection beyond the line of the stairways, the balustrading being returned round to enclose it.

In this instance the steps are spaced $11\frac{1}{2}$ inches from nose to back, and with 6 inches rise, giving easy and convenient "going." They are supported on strong walls, the ends being carried well over and bedded solid therein. The moulded strings are cut in sections as shown in detail at Y, the upper portion (forming the rake) and the bottom bed being coincident and in the same plane as the beds of the masonry in the supporting wall.

The balusters are cut in one piece, and can either be secured with dowels (see Chapter XII. Part II. Volume I.) or, if the stone is of such a nature as to admit thereof, by tenoning the balusters and sinking a corresponding mortice in the stone below. The handrail is furnished with mortices corresponding with tenons on the heads of the balusters in the same manner, and the latter are secured in the usual way with cement. In heavy work, where moulded balusters are employed, the lower member is worked on to the upper stone of the raking plinth, and the upper on the under side of the handrail, forming a base and cap respectively to the mouldings of the baluster as shown at Z in Fig. 136. The landings may be in two or three slabs, joggled together as already illustrated (see Chapter XII. Part II. Volume I.), the stones being without joint from front to back and having a bearing on the outer and main walls.

As an additional precaution, a flat arch of equal camber to that supporting the outer wall might be carried from the supporting walls of the top steps of each flight to support the landing.

The centre bay of the front is made up of a flat arch with salient voussoirs, springing from low piers with abutments on the outer faces to counteract the thrust.

This admits of an opening for light and air to a vault below, should convenience require it.

The alternate voussoirs project beyond the general face of the arch, and are carried up to the under side of the string, additional stability being thus ensured. The intermediate voussoirs are moulded.

As regards the system employed in bringing the rough material to its necessary shape for setting into position in the structure, it will be sufficient to detail the process as regards one or more of the more important stones.

As an example, the selection of one of the stones forming the raking string may prove most appropriate.

It is customary in all cases to commence by bringing one of the faces to a plane surface, usually one which forms a bed. At X, Fig. 136, the top plan or bed mould of the stone A on the general drawing is represented, while Y illustrates the side elevation, and Z represents the end elevation.

A rectangular stone is required, of a length equal to the extreme length, a height equal to the distance from the bottom bed to the apex of the top baluster base, and of width sufficient to contain the stone from back to front plus the salient moulding.

The *modus operandi* is as follows:—

Bring the bottom bed to a plane surface, and work the internal vertical face to a plane surface at right angles to the bottom bed. By means of the bevel, scribe on this face the outline of the baluster bases. Next, work in the two joints, taking care to cut them accurately at right angles to the raking surface. Lastly, indent the mouldings on the two joints and work them through, together with the set back of the bases. Cut down the superfluous stone between the bases already indented on the inner face. The splays are then drafted and the whole stone fine dragged. The operation is then completed.

In a stair with the supporting walls curved on plan, face moulds would be required both externally and internally, and the stone would have to be first brought to a convex form on the outer and concave on the inner surface by means of boning lines from top to bottom.

The stone would then form a segment of a hollow cylinder. The moulds would be found by developing the external and internal elevations, as explained in the case of arches circular on plan. For the outer mould it is necessary to cut templates of contrary outline, *i.e.* to make the mouldings recessed instead of salient on the templates, as shown at Z_1. By this means and the frequent application of the hollow moulds to the work any inaccuracy is avoided.

It is important to note that in a great deal of modern work stone is not used structurally, but the appearance of solid masonry is given by supporting the stonework upon iron joists and girders, as explained in Volume IV.

NOTE.—The methods of stone-cutting, etc., explained in Chapters VI. to XII., are those enunciated in Gwilt's *Encyclopedia*, Purchase's *Practical Masonry*, and other books. These principles are well recognised, and it has been impossible to depart from or improve upon them. Although the examples given are in many cases fresh, acknowledgment of indebtedness to previous writers on the subject is due.

CHAPTER XIV

GENERAL DETAILS OF MASONRY—CLASSIC

(*Contributed by Walter Hooker*)

In this and the following chapter no attempt will be made to do more than describe architectural features from the structural point of view, so far as they apply to masonry. It is not the primary object to give lessons in architecture. At the same time, the illustrations are selected as far as possible true to style, archæologically correct, and artistically unobjectionable.

Plinths

In order to give that stability and spread to the walls at the base of a structure which is necessary to provide a solid foundation, and at the same time to economise both in weight of superstructure and material, recourse is had to simple bands or a series of such termed Bases or "Plinths." These devices act as a means of leading the eye from a too abrupt transition from the solid mass of wall arising out of the ground to the lighter upper parts, and when treated on an artistic basis tend to soften the abrupt change caused by the diminution of the wall face.

In Classical examples, plinths are usually composed of a base course finished with more or less elaborate mouldings, as in Fig. 137, these being usually either parts of conic sections or of circles, as their characteristics more nearly approach the Grecian or Roman types.

It will naturally occur to the professional mind that the fundamental principles in designing base mouldings would be—1st, the protection of the joints from wet by keeping them in the recesses of the mouldings as far as possible ; 2nd, not to arrange any of the members in such a manner as to present cavities or hollows for wet to lie in.

These two points being duly considered, there yet lies a large field for artistic variety in the arrangement of the members, either in Classic, but more particularly in Gothic structures (see Chapter XV.).

Above the base a band of ashlar, of varying height proportionate to the superstructure, is often applied.

Cornices, Parapets, etc.

In the completion of structures of Classic design a finish is given to the building by a cornice of more or less magnitude. Properly so called, the purely Classic designation would be "entablature," which is divided into cornice, frieze, and architrave.

The generally recognised use of a *cornice* is to protect, by its overhang, the wall faces below it, and also to form a bold and artistic finish to the work.

There is generally a top moulding, known as the *cymatium*, either ovolo, hollow, or of double curvature, and below this a plane vertical face known as the *corona*, these two together forming the cornice. The soffit is sunk to form a drip, and is often carried, æsthetically, by *modillions* or consoles, and always

Fig. 137.

by a *bed moulding*. The whole is surmounted by a *blocking course*.

The *frieze* is usually a plane or convex surface immediately below the bed moulding of the cornice, serving to accentuate the mouldings of the cornice, and acting as a contrast between this and the architrave. It is customary in many cases to ornament the frieze with pateræ and carvings, often of very rich design and frequently composed of sculpture.

The *architrave* of one or more plane faces occurs below the frieze, from which it is separated by a small moulding, often enriched by carving. Fig. 138 roughly indicates the meaning of these terms.

Bands and Strings

These are horizontal courses of stonework, usually moulded, projecting from the face of the wall, and

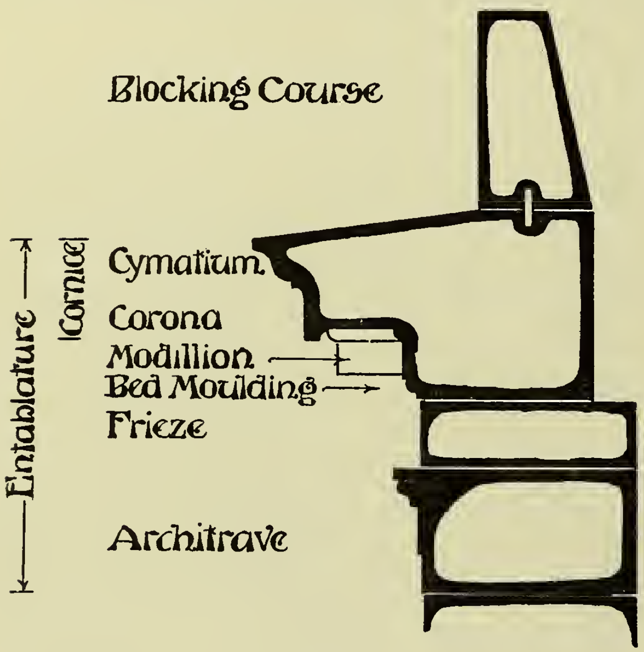


Fig. 138.

serving to demarcate the various storeys of a building. They also protect the immediate joints below, and to this end should be boldly projecting, and with the upper surface splayed to prevent lodgment of water, whilst

Fig. 139.

the lower is undercut or throated to throw off water from the face of the work.

Fig. 139 illustrates some more ordinary forms of Classic strings.

Sometimes the use of corbelling is practised, the intervals between the corbels being arched, and a projecting cornice proper completing the whole, as in Fig. 140.

In Renaissance work parapets frequently take the form of balconies, with broad piers interspersed at regular intervals, as shown in Fig. 141.

Buttresses and attached pilasters and columns are used to strengthen and support walls where concentrated weight or thrust is to be resisted. In most vaulted buildings buttresses are of common use, and are in fact essential, unless the main walls are of such a thickness as to dispense with their employment.

In Classic and Renaissance work, where provision of

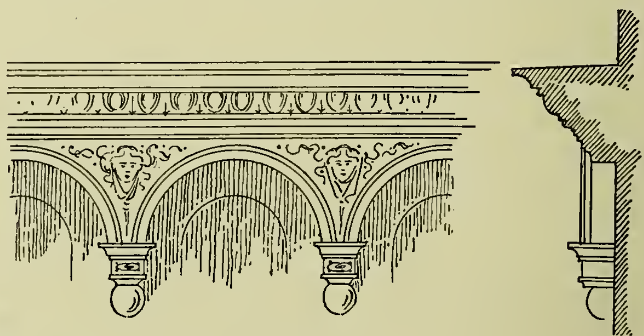


Fig. 140.

this nature has to be made, the buttress often takes the form of columns interspersed along the face of the wall, either separated from the main fabric (being connected at the base and caps by the entablature which they support) or as pilasters intimately bonded with the wall throughout their length.

These would naturally follow the general character of the design as to mouldings and proportions. An example of the use of columns as additional supports against thrust may be seen in the full-page drawing of the entrance to dyehouse (see Figs. 129, 130, and 131). Here the thrust due to the dome is taken up at the salient angles, which are the weakest points of the supporting wall, by the half-round columns which have been introduced to strengthen them at these points.

In columns, the proportions for modern work are similar to those used in ancient Greece and Rome. These proportions are based on the ratio of the lower diameter of the column—measured just above the apophoge, or small curve connecting the shaft to the base—to its height, and vary with each Order, and to a certain extent with the taste of the architect.

Pilasters differ from columns only in plan, being square instead of round in section. Their proportions are much the same as are those of columns of the same Order.

They are employed in halls, churches, etc., to save room, for, being seldom projected more than a quarter of their diameters, they do not occupy the space that a column would do. Their bases and capitals should be similar in profile to the columns of which they form a sequence.

When heavy vaults are introduced into modern churches and cathedrals, wherein clerestories are associated with aisles, the employment of flying buttresses may be required. It is almost impossible to bring such features into line with the requirements of Classic ornamentation, and though examples exist in which it has been done with astonishing success, it is customary to hide them by screens of masonry or some other method.

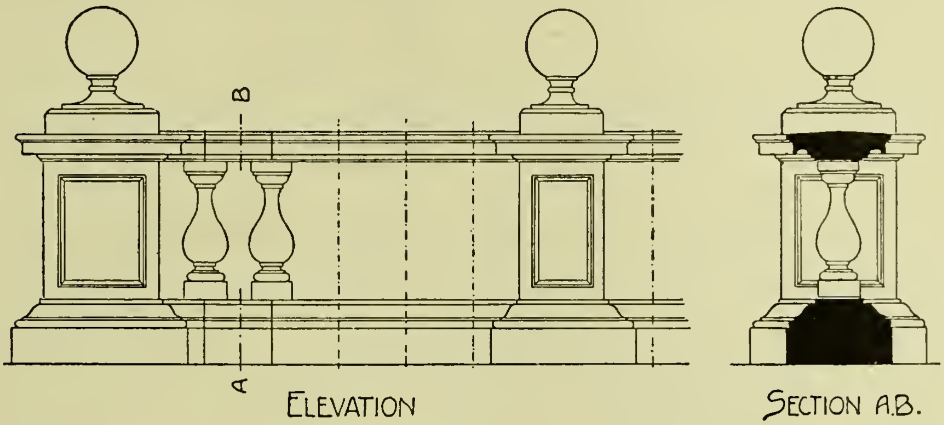


FIG. 141.

Windows

In modern Classic work the windows have either square heads surrounded with an architrave mould (Fig. 142) or some other form of ornamentation, or else are semicircular, with an architrave and hood-mould or a complete entablature following the curve of the arch (Fig. 143).

In the latter case pilasters or small columns are also frequently employed to decorate them, finished with an entablature and pediment, enclosing a tympanum partaking of the features of the style in which the building is designed (see Fig. 143). The head is usually in one stone or, if jointed, built up on the principles illustrated in the page illustration of a mausoleum (Plate V.). In the latter case the arch is composed of voussoirs or arch stones radiating from the centre, the arch being always of semicircular form.

Doorways

In the Classic and Renaissance varieties of doorways the heads are usually horizontal, or in other words a "lintel" is inserted to form the head, with a relieving arch to throw the weight of the superincumbent wall on to the abutments. In many doorways of this style the arch is made a feature and turned over as a semicircle, with moulded architraves and other ornamentation. Where this type is used and the intervening space is filled in with a window, the lintel becomes distinct from the arch, and does not serve as a support. It is then termed a "transome," acting then as a bond stone instead of a weight carrier.

In modern work doorways are frequently ornamented by pilasters and columns, with entablatures, tympanums, and pediments complete, partaking of the general characteristics of the style of Classic architecture used in the work.

It is a feature in modern construction frequently to case the heads with stone in imitation of a lintel composed of several distinct voussoirs jointed together.

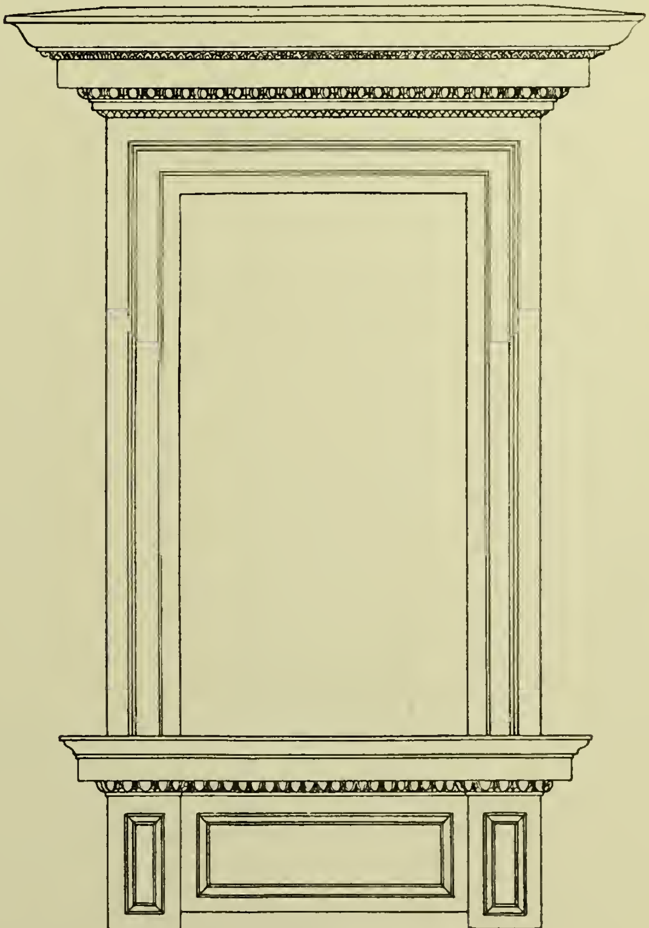


FIG. 142.

The backing in these cases, where necessitated by large openings below, is composed of massive steel

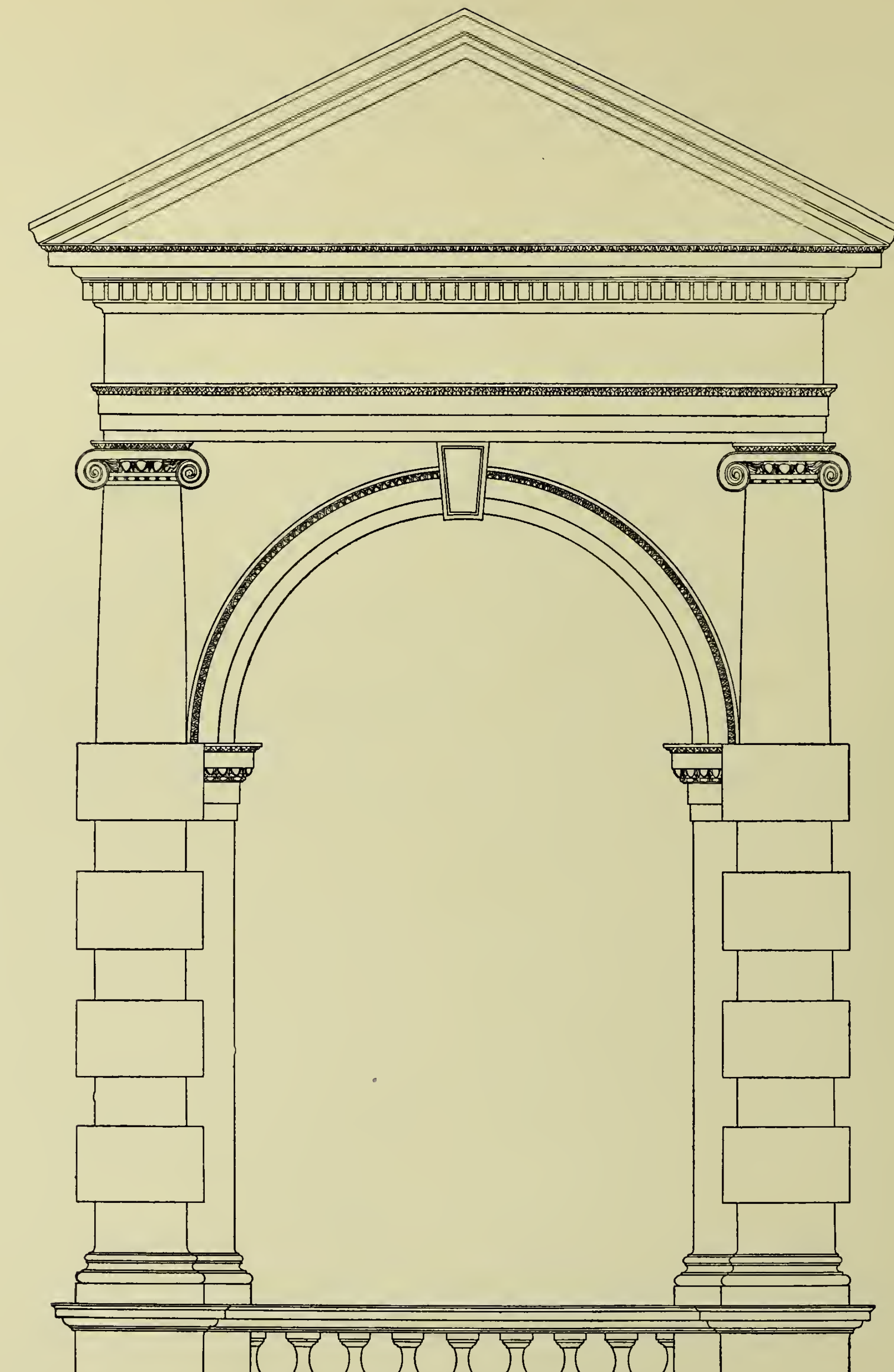


Fig. 143.

girders, which take the weight of the superstructure and thus relieve the lintels of any strain.

It has already been stated, the main distinguishing features of Greek and Roman mouldings and their modern equivalents, are their adaptation from sections of the cone, *i.e.* the parabola, hyperbola, and ellipse in the first case, and from the circle in the second.

In the Grecian style the distinctive feature is the great beauty of the curves produced by the application of the conic section to the mouldings in use therein, as illustrated in Fig. 144. The reference letters indicates the names of the mouldings:—*a*, cavetto; *b*, scotia; *c*, cyma recta; *d*, cyma reversa; *e*, echinus; *f*, ovolo; *g*, torus. The Roman forms of these, similarly lettered, are shown in Fig. 145.

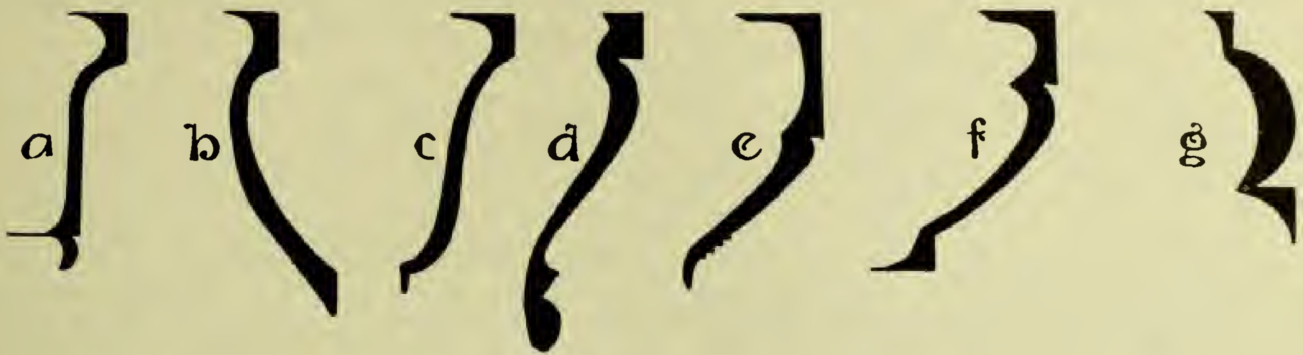


FIG. 144.

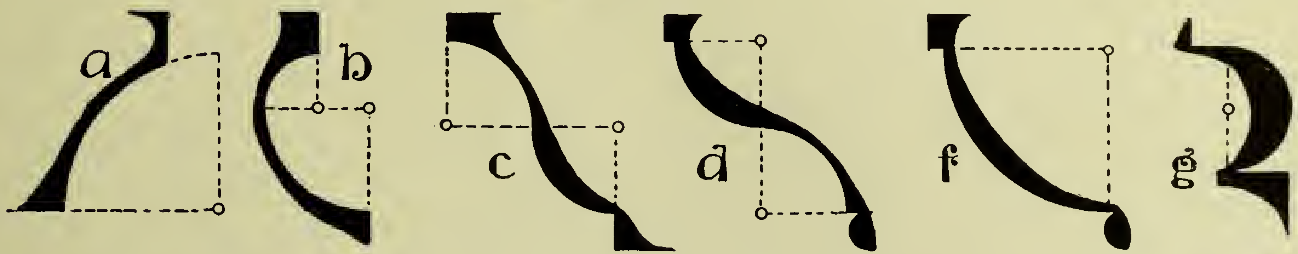


FIG. 145.

From these and their combinations the majority of modern mouldings are obtained, coupled with plane faces and chamfers.

CHAPTER XV

GENERAL DETAILS OF MASONRY—GOTHIC

(*Contributed by* WALTER HOOKER)

PLINTHS

FIG. 146 gives a few types of Gothic plinths. It will be seen that the joints are arranged to come under projecting mouldings, which are designed to make water falling upon them drip clear of the wall.

BANDS OR STRING COURSES

Often strings, more especially in Gothic buildings, by following the curves of the arches, either of windows and doors if external or of the nave arches internally, serve to accentuate the arch mouldings and also externally to protect the tracery from the weather, etc. The more appropriate term for those occurring on the inside of structures is hood-moulds. Fig. 147 illustrates a few forms of Gothic string courses, such as might be used either horizontally or as hoods. When horizontally applied in Gothic structures they particularly serve to unite the buttresses, piers, and other parts of a building, by being carried round them, also frequently forming a basis on which the sills of the window rest.

In shafting, frequent use is made of strings or bands, so as to break the uniformity of clusters of columns of great height, forming a rest for the eye and giving an appearance of tying in and strengthening the groups.

CORNICES AND PARAPETS

In Gothic buildings, in addition to a cornice moulding, the parapet is of common application, serving to hide the guttering and the junction of the roof with the wall, and also to lessen the effect of excessive height caused by a steep pitched roof. Such parapets are frequently ornamented either by crenellations or battlements, as in Fig. 148, or by tracery, as in Fig. 149.

A parapet has also a further use in cases where side thrust is to be met in the wall, tending to neutralise its effect by supplying extra weight in the abutment.

In the design for Tooting Wesleyan Chapel (Fig. 150), by Mr. J. S. Gibson, F.R.I.B.A., the angle buttresses of the tower are connected by a parapet with recessed arcadings with traceried heads, the upper portion of which are cut as battlements.

In this case the walls are not pierced for the tracery, the recessing being of sufficient depth only to afford a distinct enough contrast between the face of the wall and the panelling.

BUTTRESSES

These project from the normal wall face more or less in accordance with the strain they have to resist. This strain may result either from the thrust due to the principals of a wooden roof, in which case they are placed with the same intervals of space as the principals, and so as to take up the strain; or they may serve to take up the thrusts imposed on the substructure due to the vaulting should this be employed.

They are economic, inasmuch as by their use the greatest strength is applied only where most needed, and the spaces between the buttresses may be filled by lighter walls, and also pierced by windows for light without danger to the stability of the general fabric. They also have a distinct value from a decorative point of view.

In proportioning a buttress, diagrams should be made illustrative of the direction of the thrust due to the weight of vaulting and roof, and a polygon of forces should be constructed giving the line of the resultant of the forces; and from this the proportion of the buttress and the positions of its set backs can be ascertained.

It is frequently the case that the resultant of forces is of such a nature that buttresses of great size would be required altogether disproportionate to the general features of the building. An avoidance of over heavy and unsightly masses of masonry can frequently be made by applying, as in mediæval times, pinnacles over the head of the buttress, thus gaining weight without clumsiness. These additions may be made very important and valuable features, and add to the beauty of the general structure by careful treatment, combining both utility with ornament.

Fig. 150 illustrates the application of buttresses to the angles, and exhibits the set backs with their moulded weatherings.

The apices are planned on a cruciform basis of major proportions, with a minor cross penetrating the major one and at right angles to it, the whole being surmounted by a pinnacle with carved crockets.

In church architecture cases arise wherein the buttress is employed to sustain the thrust of ribbed roofs in the aisles, but above the aisles rises the clerestory wall, carrying the nave roof, which is also vaulted.

To meet the thrust due to this vaulting, and to avoid unsightly masses of masonry, flying buttresses are employed. These are half-arches springing from the buttresses of the outer aisle walls over the aisle roofs, and impinging on the clerestory walls at or near

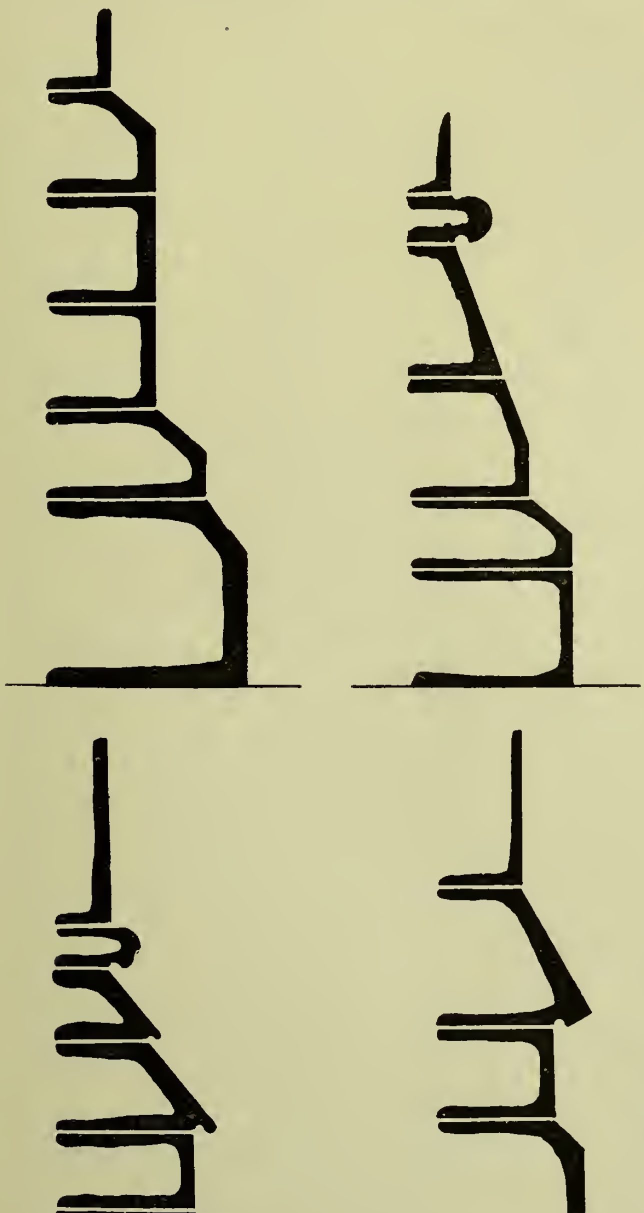


Fig. 146.

the springing of the ribs of the nave vaulting. They are employed to counteract the thrust caused by the main vault, or, more properly speaking, to transmit it to the outer buttresses. They lend themselves to considerable ornamentation.

The arches should be of flat sweep. The upper surface may be channelled, and utilised to lead the water from the clerestory guttering to the outer walls, or may be saddlebacked.

In certain situations and under certain conditions

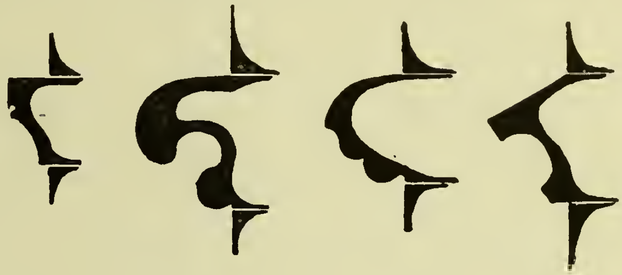


Fig. 147.

double flying buttresses are employed. These are more particularly applicable where thrusts are to be met at more than one point in the clerestory wall, generally where there is much difference in height

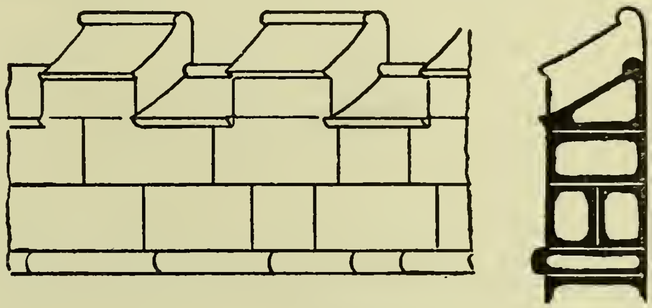


Fig. 148.

between the aisles and the transepts. An illustration (Fig. 151) is given of a buttress of this kind.

It will be noticed that the buttress is carried well above the junction of the upper flier, neutralising by its added weight the outward thrust of the arch.

Piers

This term is more particularly applied to the supports of heavy superstructures, whether of simple, square,

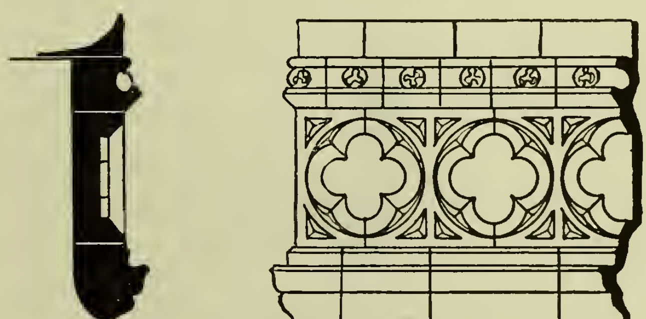
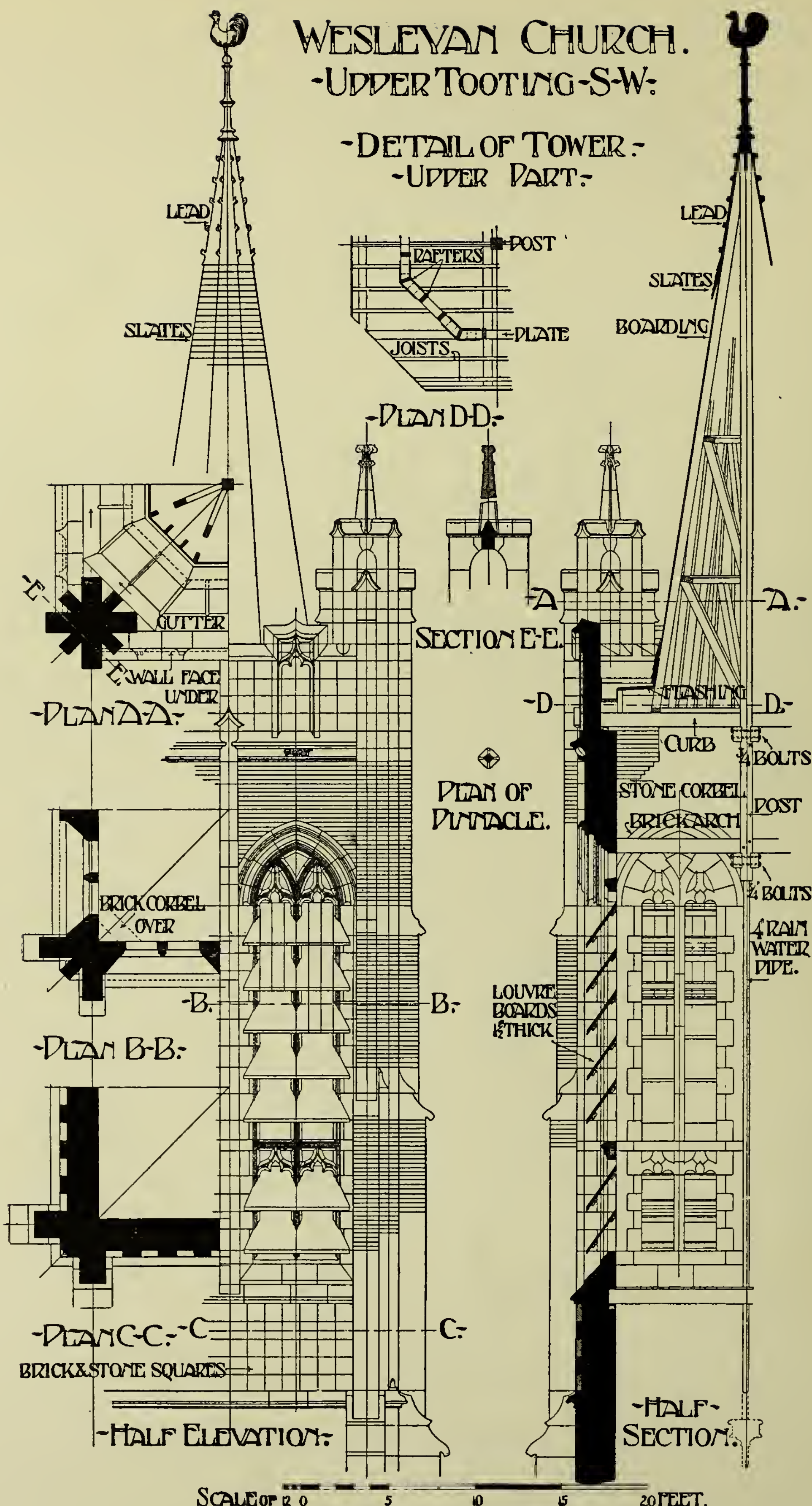


Fig. 149.

or octagonal plan, or with engaged shafts forming an integral part of the main structure. The term is more generally used with regard to Gothic or Romanesque architecture than to Classic, wherein the term column is usually applied to such cylindrical bodies.

The pier may be, as above stated, either plain or with



WESLEYAN CHURCH.
-UPPER TOOTING-S-W-
-DETAIL OF TOWER-
-UPPER PART-
LEAD
SLATES
POST
RAFTERS
PLATE
JOISTS
-PLAN D-D-
LEAD
SLATES
BOARDING
E
GUTTER
E
WALL FACE UNDER
-PLAN A-A-
SECTION E-E.
A
A
D
FLASHING
D
CURB
4 BOLTS
PLAN OF PINNACLE.
STONE CORBEL
POST
BRICK ARCH
4 BOLTS
BRICK CORBEL OVER
4 RAIN WATER PIPE.
B
B
LOUVRE BOARDS 1½ THICK
-PLAN B-B-
-PLAN C-C-
C
C
BRICK & STONE SQUARES
-HALF ELEVATION-
-HALF SECTION-
SCALE OF 12 0 5 10 15 20 FEET.

FIG. 150.

detached shafting connected at the base and caps with a main trunk, or with shafts attached thereto (see Fig. 152).

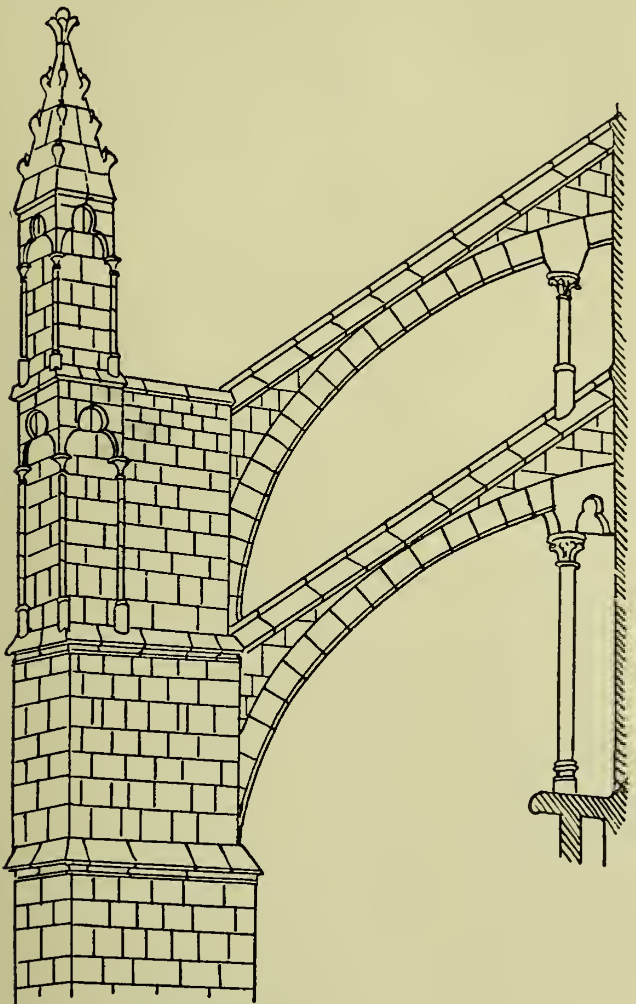


Fig. 151.

Bases and Caps

Bases are near akin to plinth moulds in their general characteristics, more especially where employed externally. Their mouldings should be designed to protect the stone below from injury by wet, and also with a view to prevent lodgment either of rain or dust.

Fig. 152.

With those used for internal purposes the need for guarding against the lodgment of rain does not apply, and therefore the application of deeply under-cut members is admissible and even advisable, as giving great artistic results from the contrasts of light and shadow thereby presented to the eye. A few examples are shown in Fig. 153.

When circular bases rest on square pedestals, they either overhang or else the corners are filled with a carved enrichment, as in Fig. 154.

Fig. 153.

Caps, although not always used, have a distinct value in intercepting the lines of the arch mouldings, and acting as a stop, more especially where the arch mould is not continued down as a pier and a different plan is applied to the latter.

In some cases, however, the use of the cap may be dispensed with, as, for instance, where a plain cylindrical

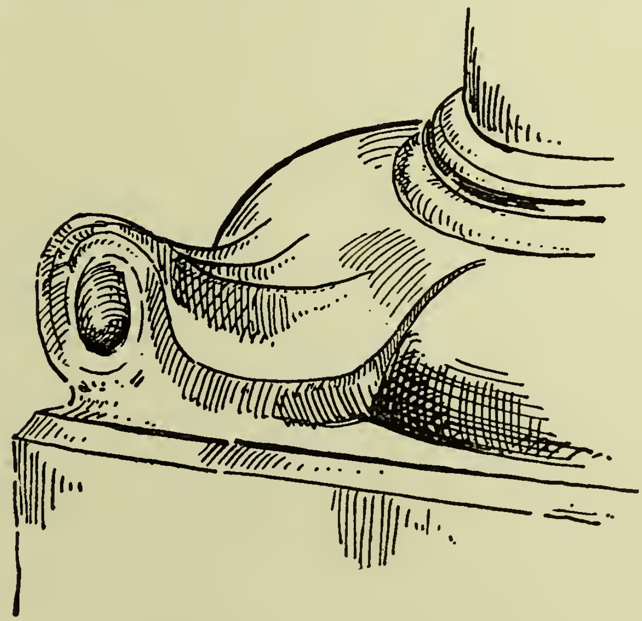


Fig. 154.

pier meets a series of arch moulds or vault ribs and the moulds are allowed to die into the contour of the cylindrical face (see Fig. 154).

Caps, generally speaking, and using the term as applied to Gothic buildings, admit of an infinite variety of both form and decoration.

The more simple forms comprise a rounded necking

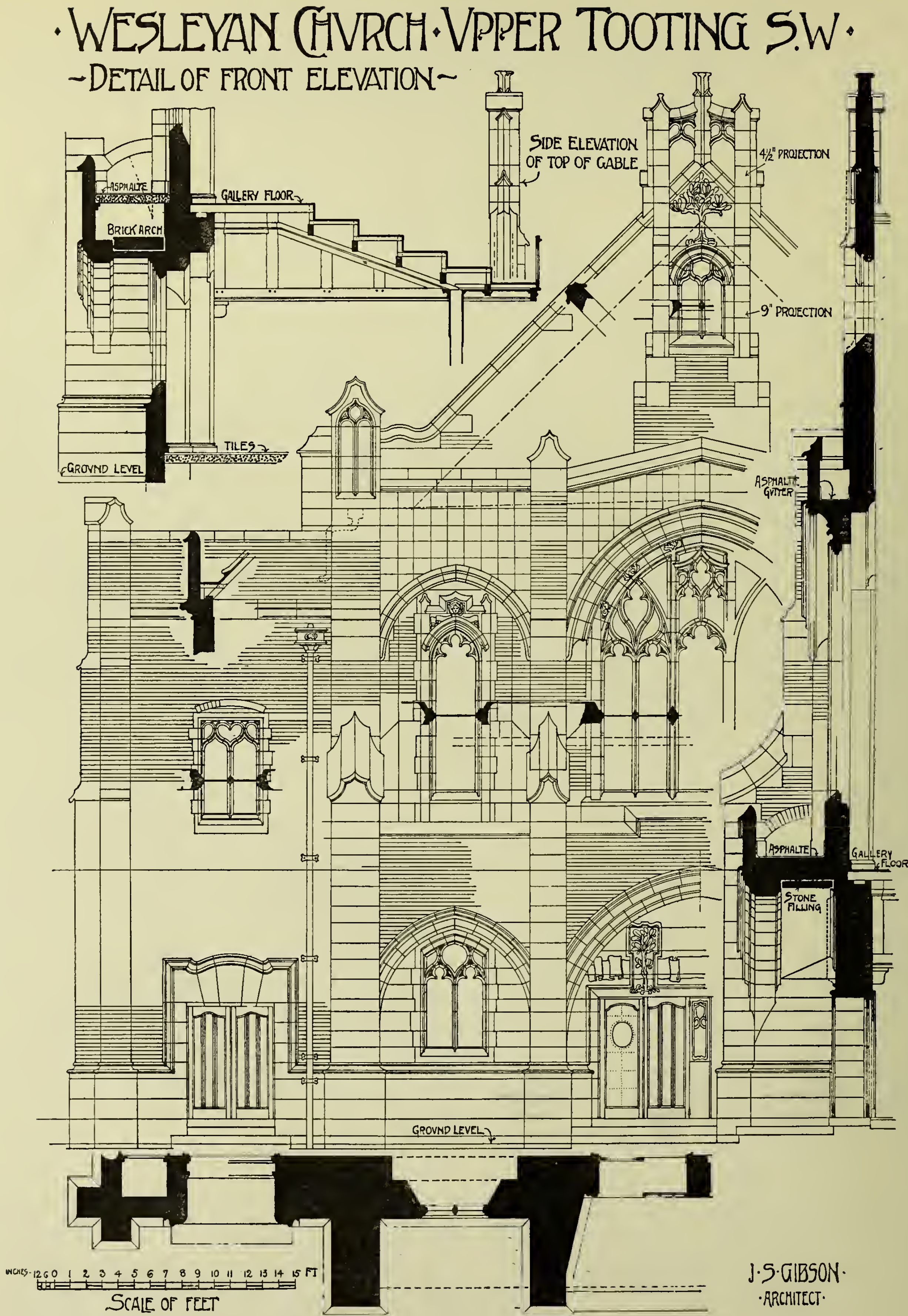

·WESLEYAN CHVRCH·VPPER TOOTING S.W·
~DETAIL OF FRONT ELEVATION~
SIDE ELEVATION OF TOP OF GABLE
4½" PROJECTION
9" PROJECTION
ASPHALTE
BRICK ARCH
GALLERY FLOOR
TILES
GROUND LEVEL
ASPHALTE GVTTER
ASPHALTE
GALLERY FLOOR
STONE FILLING
GROUND LEVEL
INCHES 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 FT
SCALE OF FEET
J·S·GIBSON·
·ARCHITECT·

FIG. 155.

as the lower member with a salient intermediate, and with a moulded abacus, or even a plain table, square on the face, but following the general plan of the pier of which it forms the finish.

An elaboration of this is produced by carving the intermediate span or belt. A few examples are shown in Fig. 157.

Examples are also given in Fig. 155, which illustrates, the doorway of Tooting Wesleyan Church, where the

FIG. 156.

mouldings of the archway are shown dying into the reveal of the buttresses on either side, each mould and member being carried on in its regular sweep until it meets the vertical face of the buttress, which here may be taken to act as a pier. The stones of the buttress would in this instance be cut in the rough, of sufficient projection where the springing of the mouldings occurs to take up a portion of the arch and form on the front face a joint or series of joints radiating from the arch centre. It may be noted that the covered porch formed by this large arch serves to protect the outward opening door against the inclemency of the weather.

Similar treatment will be observed in the arches over the windows on the ground level.

FIG. 157.

Figs. 150 and 155, reduced from Mr. Gibson's working half-inch scale drawings, are admirable illustrations of the way in which such drawings should be prepared for the mason's use.

In the above cases the vertical wall is square on plan, and the junction is much more simple, therefore, than where vertical cylindrical faces have to be met. An example of a moulding dying on to a splay is shown in Fig. 158.

WINDOWS

The simplest type of Gothic window is undoubtedly

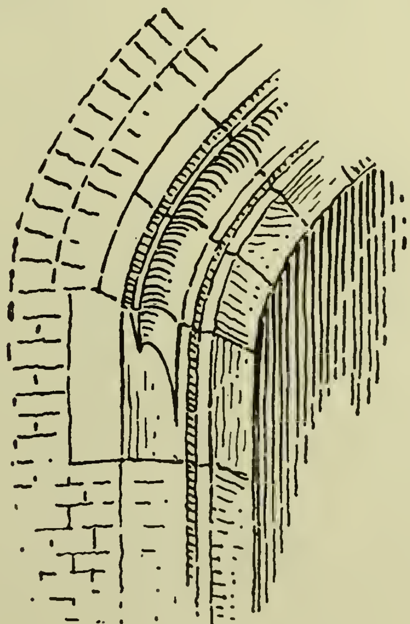


FIG. 158.

the lancet, being, as the name implies, long and narrow, the head being formed of two arcs meeting at a point more or less acute. An example is given in Fig. 159.

This type may be either employed singly or grouped. In the latter case it is usual to carry the central window to a greater elevation than the outer ones.

A somewhat more elaborate type is shown in Fig. 160, wherein the window is composed of two lancets with a mullion dividing them, and united under one main arch. The space between the small arches and the main arch is composed of plain masonry pierced with a quatrefoil. This type of tracery is called "plate tracery." The plans drawn to a large scale in Fig. 161 show how the jams, abacus, and arch moulds are superimposed over

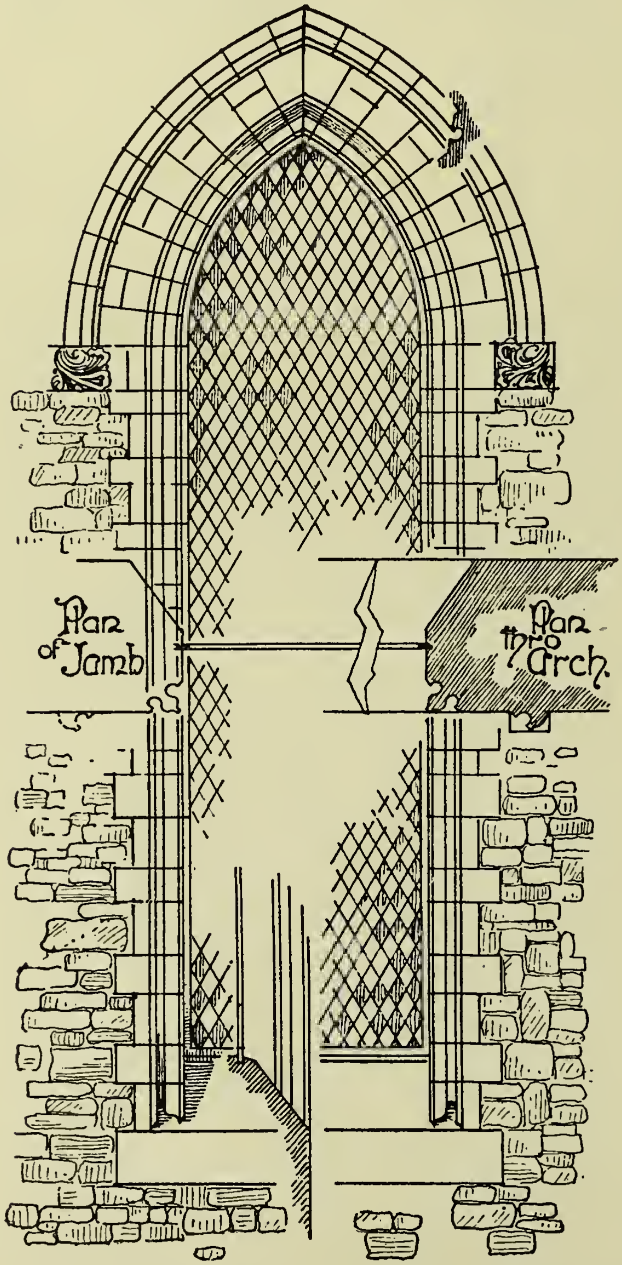


FIG. 159.

one another, and also how the mouldings are worked out of the various stones.

In this case a quatrefoil is shown above the lancets and filling in the blank over their junction, the whole being surmounted and enclosed by an arch with hood-mould.

It will be noticed how carefully the joints are arranged so as to avoid the mitres, provide true bedding, and allow the stones to be cut out of square blocks with little waste or labour.

A further elaboration of the above, and one that will naturally strike the observant mind, is reached by cutting away the plane faces yet left to form tracery, as in Fig. 161.

Many types of tracery will commend themselves to the student by a careful study of the many examples of mediæval architecture to be met with in England.

In tracery of a more ornate character use is made of cusping to a great extent, the plain lancet shape being replaced by a trefoil head, as in Figs. 161, 162, and 163.

These several examples are given in order to illustrate the principles of jointing better than can be done by description. The separate arch rings are kept distinct, and the tracery joints are all cut to radiate to centres, as well as to meet the requirements mentioned above.

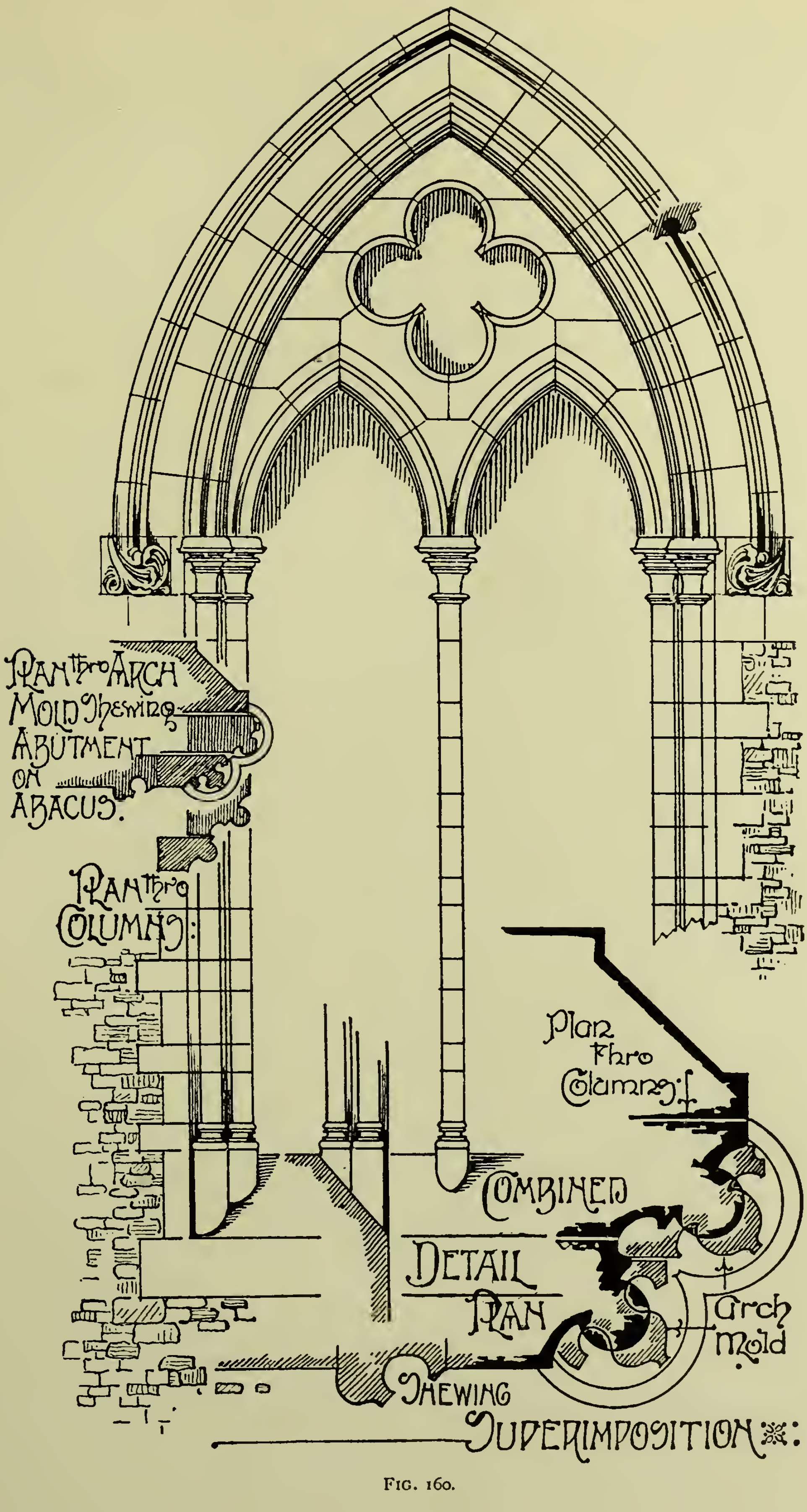
In windows of more than two mullions the traceried heads are often of an apparently much more complicated design.

This complication will resolve itself into a simple matter on further study, as all properly constituted heads are laid out on true geometrical principles. It should therefore be the aim of the architect to so set out his design as to base it in some combination of plain geometrical figures as a groundwork, and to fill in and elaborate the details to suit the foundation thus laid down.

Pursuing the subject of elaborate detail in tracery, we next arrive at the type in which the curved lines of the design are intersected by continuations of the mullions, or by what may be termed subsidiary mullions. Such a type is found illustrated in Fig. 164, which is a large scale elevation of the chancel window in Tooting Wesleyan Chapel, designed by Mr. J. S. Gibson, F.R.I.B.A. Here the centre mullions are carried upwards above the general springing line, and in the upper segments the space between is again divided by a short mullion surmounted by tracery. The outer mullions are only partially carried up, but on the other hand the spaces are subdivided over the cusped ogee arches, and the apices of the arches are continued up as mullions closely interweaved with elaborate tracery.

A similar class of window, but of more flowing lines, is given in Fig. 157, where it constitutes the gable window of the same church. In this instance the two centre mullions only rise above the springing line, and the space between is subdivided by a small mullion over the cusped arch, the sides being of the flowing or curvilinear type of window.

In cases where windows are pierced in thick walls a very fine effect can be arranged by the introduction of interior tracery, preferably with a larger opening (by splaying the space between the outer and inner tracery). This inner window would be unglazed, the outer being the window proper, and glazed. Its face would be



PLAN thro ARCH MOLD Shewing ABUTMENT ON ABACUS.
PLAN thro COLUMNS:
Plan thro Columns:
COMBINED DETAIL PLAN
Arch Mold
SHEWING SUPERIMPOSITION

FIG. 160.

kept somewhat near the main face of the external wall.

It is usual in such cases to elaborate the internal class of work, and that is the apparent as well as actual additional strength resulting in the use of the two sets of traceried windows.

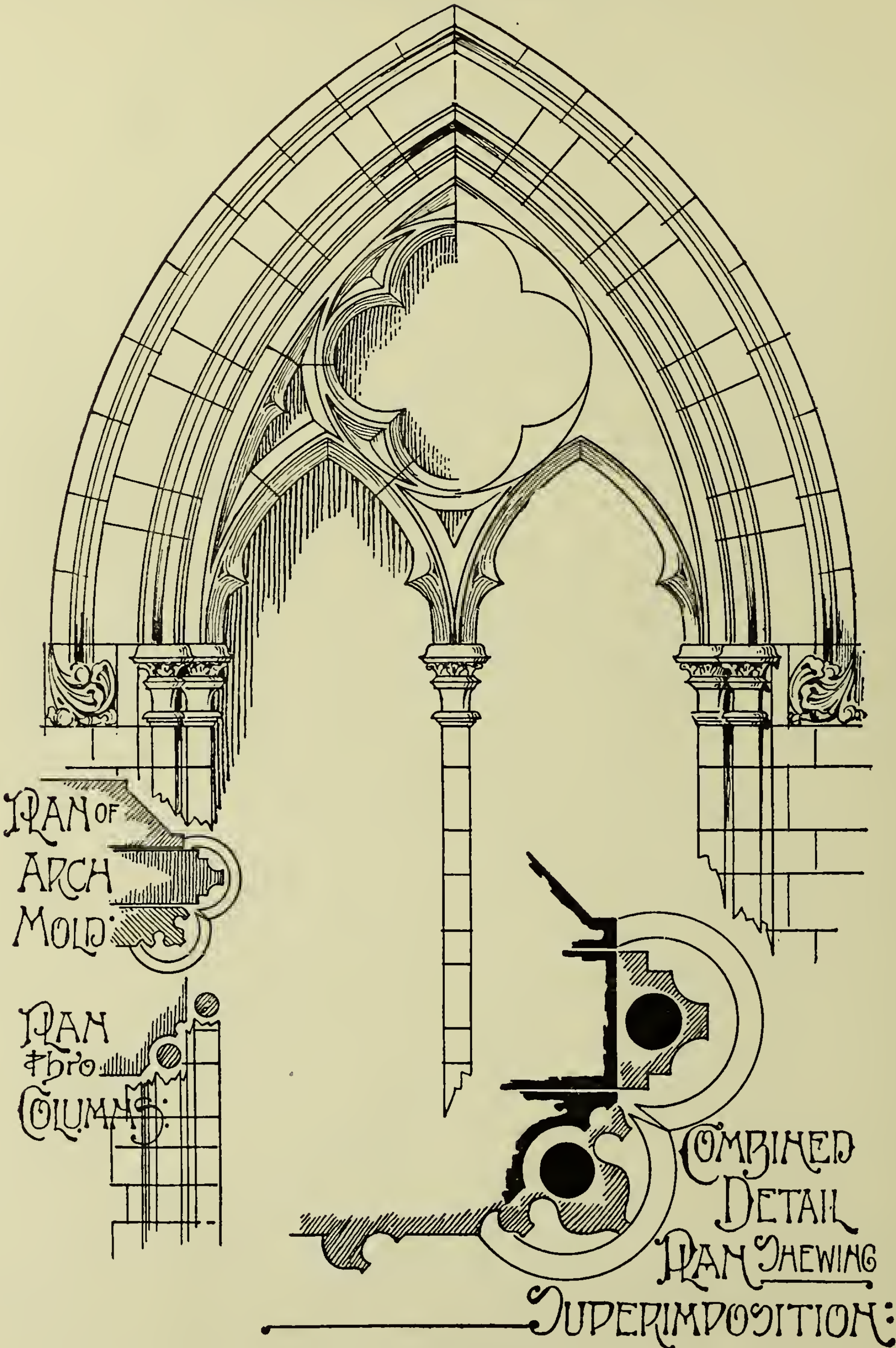


FIG. 161.

tracery to a somewhat greater extent than the external. Mullions with columns, caps, and bases are frequently introduced.

There is another feature deserving of mention in this

A plan of a window of this type will be seen in Fig. 165.

Circular windows and those of elaborate tracery, denominated rose windows, are suitable for gable ends.

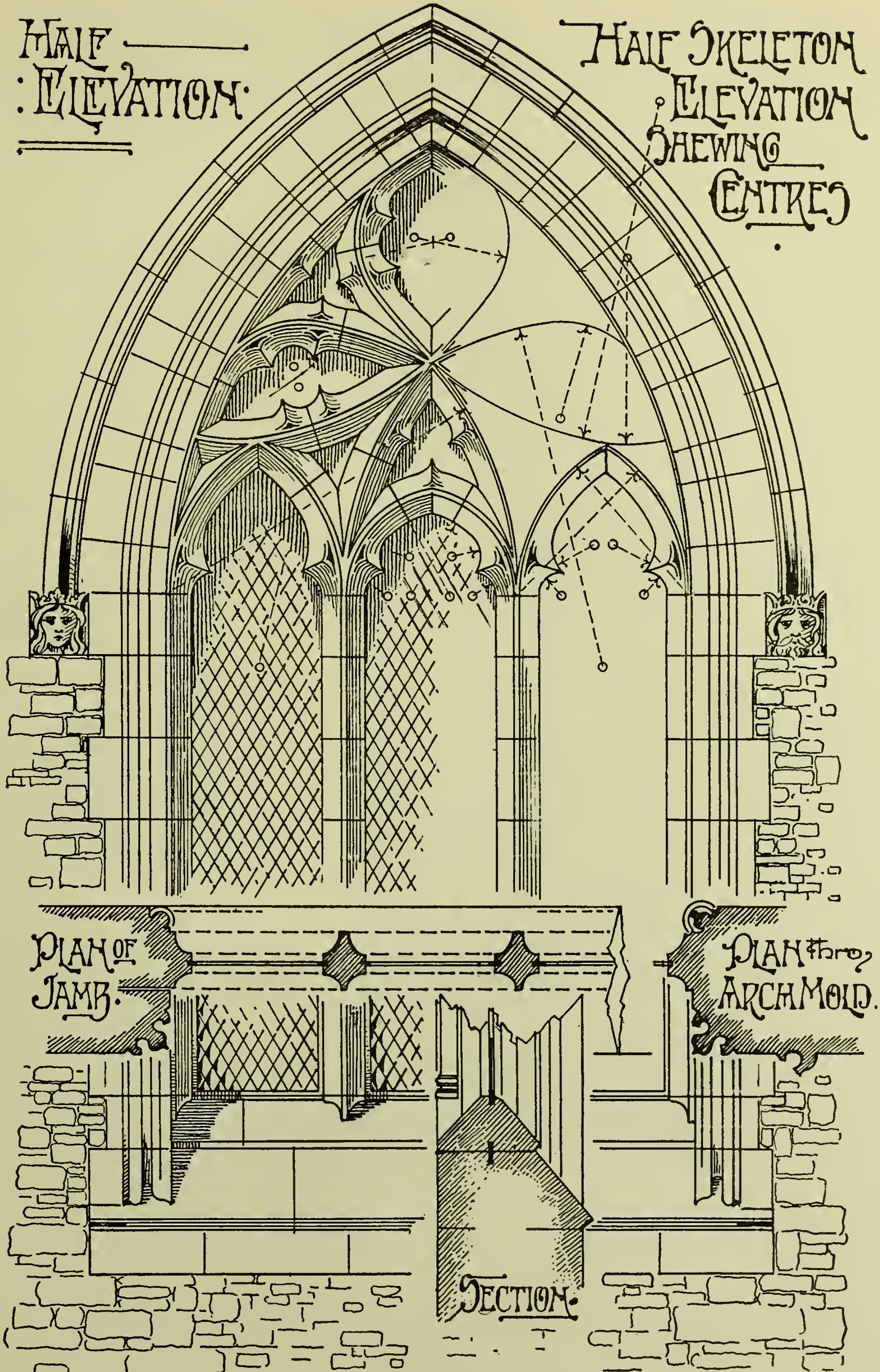

HALF ELEVATION
HALF SKELETON ELEVATION SHEWING CENTRES
PLAN OF JAMB.
PLAN thro' ARCH MOLD.
SECTION.

FIG. 162.

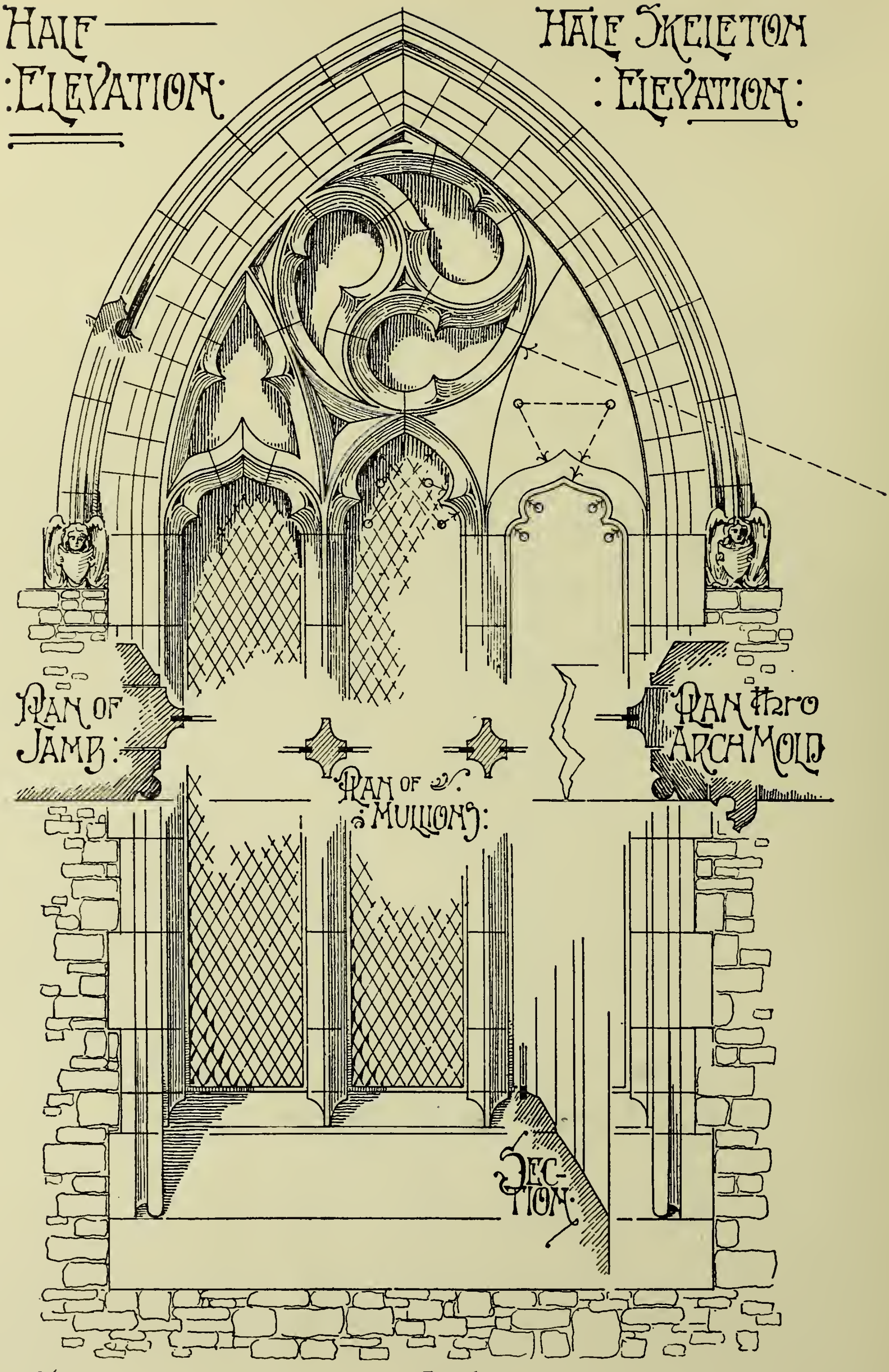

HALF
:ELEVATION:
HALF SKELETON
: ELEVATION :
PLAN OF
JAMB:
PLAN thro
ARCH MOLD
PLAN OF
MULLIONS:
SEC-
TION:

FIG. 163.

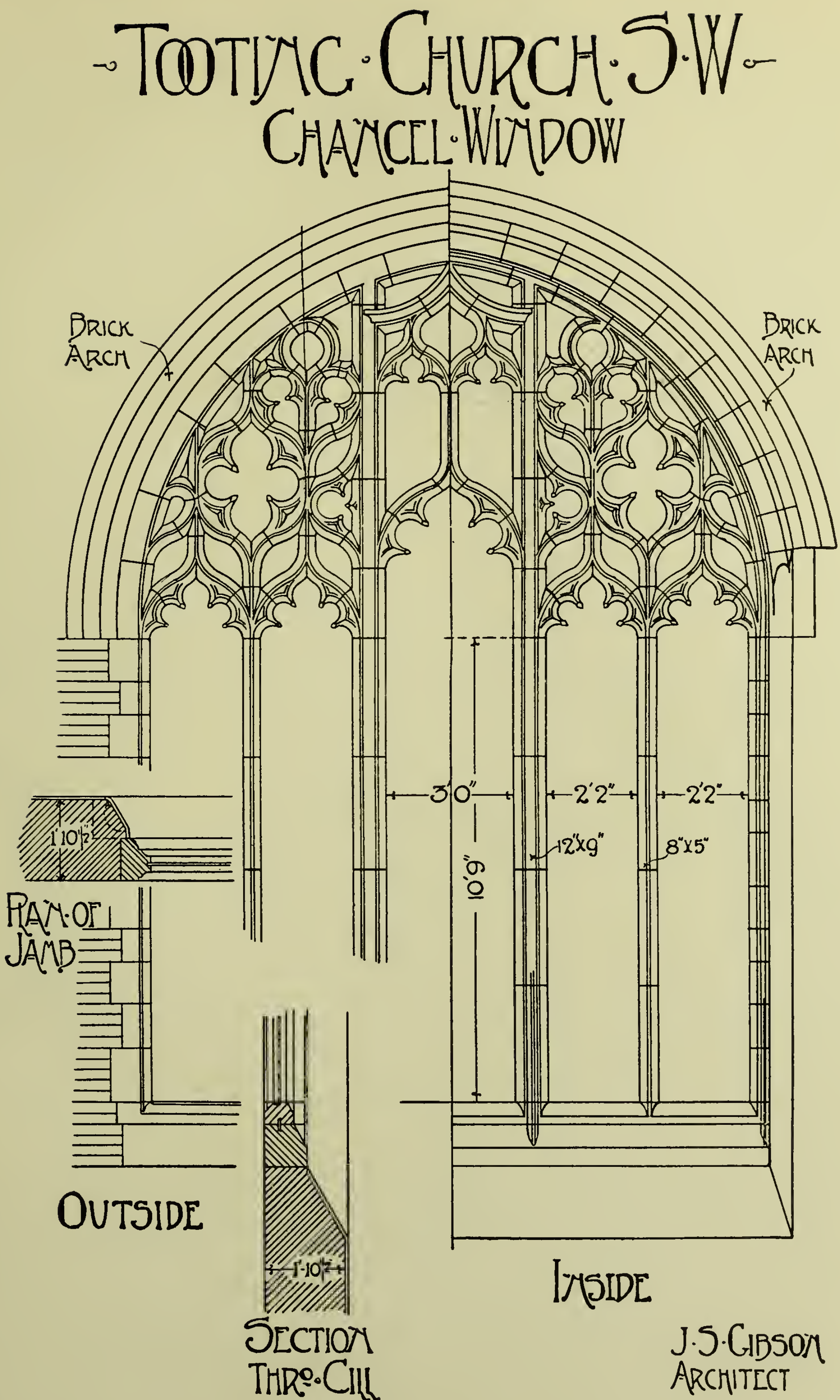

TOOTING · CHURCH · S·W
CHANCEL · WINDOW
BRICK ARCH
BRICK ARCH
1'10½"
PLAN · OF JAMB
3'0"
2'2"
2'2"
12"x9"
8"x5"
10'9"
OUTSIDE
1'-10½"
SECTION THRO· CILL
INSIDE
J·S·GIBSON
ARCHITECT

Fig. 164.

As their names imply, they are of circular shape, and may be either filled in with plate tracery with radiating mullions (whence the term "wheel" windows), or with elaborate tracery, when they are distinguished by the name of "rose" windows.

The simple varieties are usually plain circles with trefoils, quatrefoils, or cinquefoils, and their corresponding cusps inserted therein as ornament. The inner portion of the wall is usually splayed, and the sills also, to afford the greatest diffusion of light possible. The heads of the openings may be either circular, following

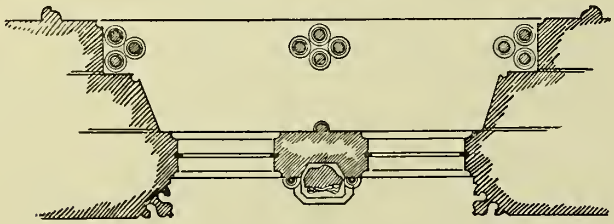


Fig. 165.

the same sweep as the upper portion of the window, or may be pointed (see Fig. 166).

Doorways

In the treatment of Gothic doorways, when furnished with lintels, the latter are usually of massive stones or have relieving arches over. The lintels may be also

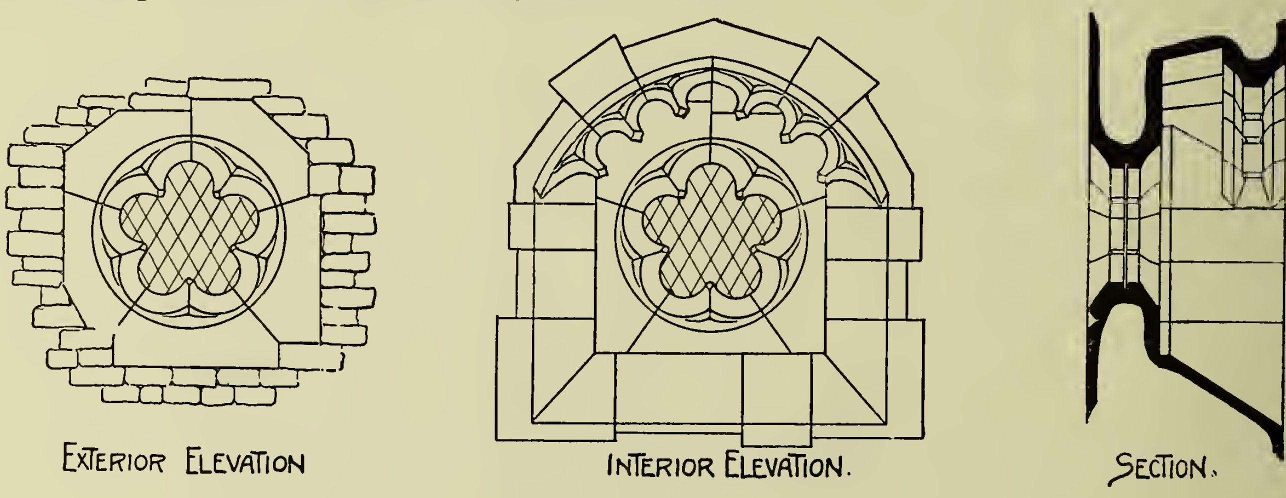


Fig. 166.

composed of several voussoirs forming a flat arch with the joints radiating from a centre equivalent to the centre of an arch if carried out in the usual method. Such lintels may have the mouldings on the jambs returned round them.

A variety may also be introduced by duplicating the doorway, the centre division being a column with cap and base corresponding to similar ones introduced in the reveals of the opening. This method relieves the strain on the lintels.

A variety is obtained by carrying up the members of the reveals in the form of an arch, and filling up the space between the lintel and the soffit with a tympanum, on which either bas-relief or heraldic devices can be carved. Lastly, the space over the lintel can be filled in with tracery and glass inserted. In this case the lintel is more properly styled a transome.

Many doorways are designed without lintels, and the doors shaped to the curves of the arch. In these cases it is necessary to provide sufficient space to admit of the doors opening either outwards or inwards, as may be required.

It is customary to carry up the reveals to such a height as to give free play to the highest part of the door when open to its fullest extent, and to carry the reveals over as flattened or segmental arches.

In the illustration of the front elevation of the Wesleyan Church at Tooting (Fig. 155) is to be found part of the front and a section of the main entrance.

The doorway proper is composed of two doors with a flat lintel over. The face is ornamented with an architrave carried up to the lintel and returned around it with scroll work and ornamental panels, with carving over the centres of the openings. By an ingenious arrangement a bold arch is thrown over between the outer member and the wall face, impinging against the buttresses on which it dies. This forms, by its projection from the main wall, a porch giving shelter from the rain, and also protecting the door proper from weather.

The outer arch is deeply moulded, and the mouldings die into the face of the vertical buttress walls, as already explained in a previous paragraph. Behind the arch, and between it and the face of the main wall, the arched space is formed, with a soffit following the lines of the outer arch, but recessed and somewhat splayed inwards.

The upper part is filled in with masonry or brickwork and finished flat, forming a floor protected with asphalt on the upper part. The outer arch is carried above the level of this floor, and finished with a horizontal moulded coping forming a parapet.

Mouldings

Gothic mouldings differ in many respects from the Classic, although some of them have a close resemblance to mouldings employed in the latter style. For instance, some Early English bases are almost identical

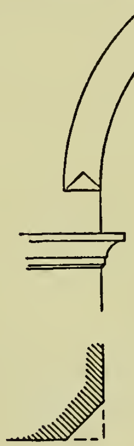


Fig. 167.

with what is termed the "attic" base, and other forms also will be seen on a close scrutiny to bear a close analogy to their Classic forerunners.

The simplest form of adornment for angles next to the square is the chamfered edge. This is devised by the cutting away of the sharp angle at an angle of 45 degrees from the face, as shown in Fig. 167 and at *a* in Fig. 168.

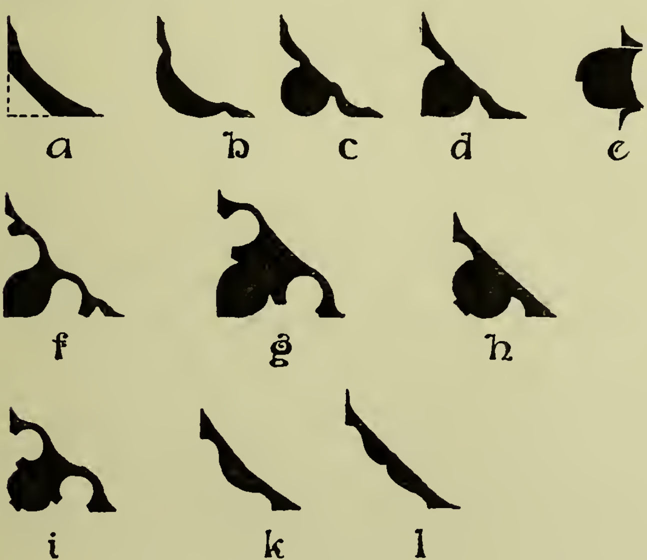


Fig. 168.

This can be terminated over an impost, if in an arch, by stopping the chamfer a little above the abacus, and cutting a double splay from the square face below to die into the chamfer (see Fig. 167). This is termed the "Broach." The next advance results in the "Edge roll" (*b*, Fig. 168), and the "Quirked bead," or three-quarter round (*c*) on the angle formed by the face and reveal of the opening.

Differing slightly from this is the "Bowtell," which is arrived at by leaving the salient angle of the above example and cutting the recessed portions or quirks (*d*).

We next have the "scroll" mould, so called from its resemblance to a roll of paper or parchment with the edge projecting (*e*).

A very effective moulding is shown in a combination of the bowtell with hollows and fillets (*f*).

Another and very striking mould is the bowtell with fillets and hollows (*g*), while the next example illustrates the application of the fillet to the bowtell (*h*), and is more of a variety of the pointed bowtell than a distinct entity in itself. Sometimes three fillets are introduced (as at *i*), at others only two, both having a certain value as ornament.

A very handsome moulding, and one that can be

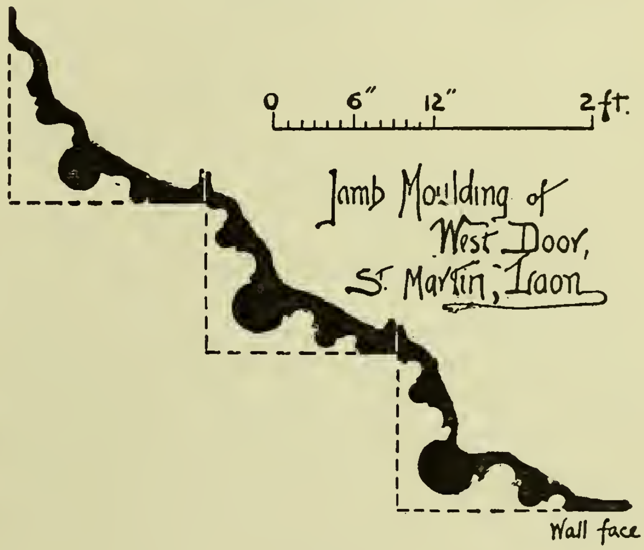


Fig. 169.

introduced in door jambs and other openings in a very effective manner, is the double ogee (*k*), while yet another moulding, closely allied to the last example, is the wave moulding (*l*).

Generally speaking, the above mouldings, grouped together in pairs or more, or arranged in sets with hollows at intervals, will serve to make up any form or grouping of moulds suitable for ordinary practice.

Variations of the above, such as flattening the fillets and bowtell moulding, are mere caprices in matters of form or indications of date, and can be introduced in any convenient number to suit individual taste,—though it should always be done with consideration for the shape of the block of stone out of which they are to be cut.

Fig. 169 illustrates a group consisting of rolls and hollows, in three ranges or tiers, the rectangular blocks out of which they are cut being readily traceable.

In grouping a set of mouldings certain rules should

be observed respecting the planes in which they lie and from which they base their departure.

The first may be taken as being parallel with the wall face; the second as a chamfer, usually at an angle of 45 degrees with the wall face; and the third at right angles.

These being set out, or any one of them, the proposed plane can be divided up in the usual way by hollows, and the groups then elaborated. Care should be taken to bring all salient points of the groups into

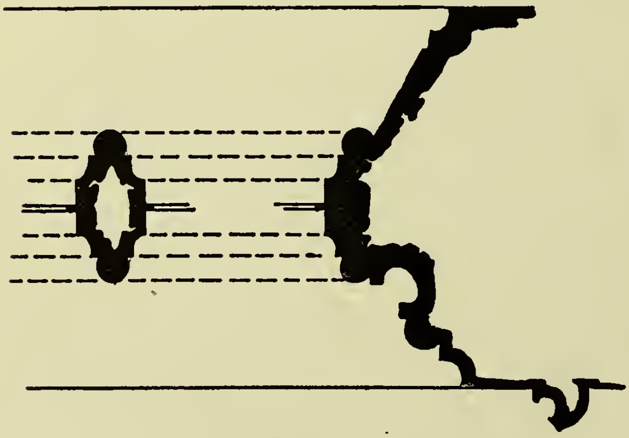


FIG. 170.

line with their respective planes, to avoid cutting on the one hand and for uniformity and symmetry on the other.

In cutting mouldings the mason will first prepare the faces or planes, as mentioned above, and, on the beds, will draft by means of a template (cut to the accurate section of the moulding) and a chisel, or pointer, the exact section of the mouldings as designed by the architect, finishing the operation as already explained in a former chapter.

In window openings the inner set or group of mouldings should coincide with the mullions (if any) of the window, so that the tracery will mitre above and present a homogeneous aspect to the eye (see Fig. 170).

MINOR ORNAMENTS

In Gothic architecture it is customary to finish the

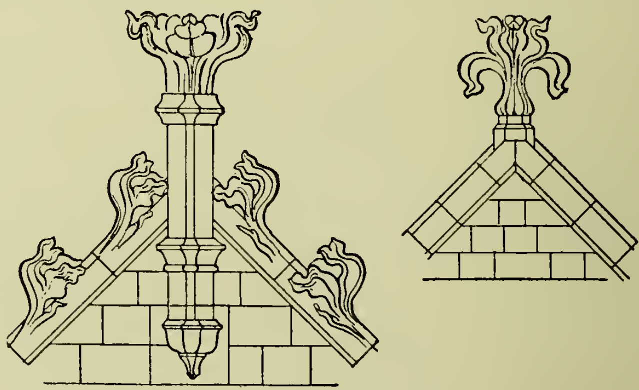


FIG. 171.

gable apices of buildings with some form of ornamentation. These may take the form of simple fleur-de-lis, or may be further elaborated in the form of pinnacles ornamented with crockets of foliated design (see Fig. 171).

An example of a pinnacle is also given in the elevation of the tower to Tooting Wesleyan Church (Fig. 150).

CHAPTER XVI

BUILDING STONE

(*Contributed by* WALTER HOOKER)

SANDSTONES

THE best known stones of this class are to be found as sedimentary rocks in the "Silurian" "Devonian," "Carboniferous," "Permian," and "Triassic" formations.

Those varieties found in the first-named formation are more used in positions where strength and toughness are required, as in engine beds, foundations, etc. Their toughness makes them difficult to work, and they are therefore not in favour where much cutting and ornamentation are required.

DEVONIAN.—The sandstones of the Devonian formation—in Scotland better known perhaps as the "Old Red Sandstone"—form a numerous class, and are to be found very generally distributed in parts of the Grampians, near Dundee, Edinburgh, Cromarty, and in Dumfriesshire. In England the countries of Hereford, Gloucester, Monmouth, and Devon form the localities mostly productive of this class of stone.

Although called the old "Red" sandstone, stones of this formation are not invariably of this colour, being at times found of a greyish or yellow colour, or of varying shades up to red.

Some of the best known quarries are the following:—

Craigleith, near Edinburgh (now almost worked out, and to a great extent replaced by Hailes stone, of similar character), a greyish sandstone exceedingly durable and of fine weathering properties, mainly composed of fine particles of quartz and mica, cemented by a siliceous material, can be got of any convenient size up to blocks 10 or 12 feet long. Its composition is about 97 per cent. of silica, 1½ per cent. of carbonate of lime, and a trace of iron. Its cohesive power is about 7800 lbs. per square inch. Specific gravity, 2.3.

Corsehill, and the neighbouring *Closeburn*, near Annan in Dumfriesshire, is a fine red sandstone, very workable, of even grain and of good weathering qualities. Composition, about 96 per cent. silica, a small percentage of carbonate of lime, and a little iron. Its specific gravity is 2.26. Cohesion, about 7000 lbs. per square inch. To be had in fairly large blocks.

In Devonshire good sandstones are found in *Newnham* and *Hangman Hill*, but they are not much known outside these districts.

There are also quarries of good and useful stone in Hereford, Gloucester, and Monmouthshire. The quarry at *Wilderness* (Forest of Dean) produces a fine hard stone of exceeding strength and resistance to crushing. Large blocks are to be procured.

CARBONIFEROUS SANDSTONES are mostly, as their name implies, obtained from the coal measures of both England and Scotland. The coarser stones of this class are used for heavy work, engine beds, bridges, etc. The finer varieties are more laminated, and are suitable for pavings, landings, steps, and copings. They are almost all durable, hard, and of great resistance to crushing, having admirable weathering properties, especially as regards resisting the action of wet and atmosphere in large towns.

Of the 'grit' or coarse stones of this class the most important quarries are as follows:—

Darley Dale.—A fine even-grained grit of a drab colour, a very good weathering stone, to be had in large blocks and long lengths. Composition, 96 per cent. of silica, a trace of carbonate of lime, and about 1.5 per cent. of iron and alumina. Specific gravity, 2.6; cohesion, 7000 lbs. per square inch; crushing strain, 670 tons per square foot; weight per cubic foot, 162 lbs.

Duffield Bank.—A fairly good weathering stone of even texture. Colour, light brown. To be procured in fairly large blocks.

Whatstandwell.—An exceedingly strong and hard stone, colour red (sometimes brown or grey), suitable for situations where heavy strains are likely to be met with. To be had in large blocks.

Matlock.—Brownish grey colour, very durable, extensively used for general building purposes where superimposed weight is to be encountered.

Stainton, Durham.—A sound hard stone of good weathering quality, of close even texture. Colour, a fine light brown.

Forest of Dean.—An exceedingly reliable and durable stone, of an even blue or grey colour, suitable for all ordinary building purposes, but hard to work. Large blocks are obtainable. Weight, about 150 lbs. per cubic foot. Contains about 96 per cent. of silica and a small proportion of carbonate of lime and alumina.

Pennant.—A tough durable stone, hard to work, of a slaty colour. Suitable for kerbs, steps, and landings, and all positions where a good wearing surface is required. Weight, about 162 lbs. per cubic foot.

Great resistance to crushing. Contains about 97 per cent. of silica.

Abercarne, Monmouth.—A good useful stone of a blue colour and fair weathering quality. To be obtained in good sized blocks.

Heddon, Northumberland. — A durable stone of good weathering quality. Colour, light brown. Weight, about 130 lbs. per cubic foot. Composition — silica, 95 per cent. ; carbonate of lime, 1 per cent. ; iron and alumina, 2.3 per cent. Cohesion, 4000 lbs.

Kenton, Northumberland.—Somewhat similar to the above-mentioned stone. It stains on being much exposed to the weather owing to the amount of iron in its composition. Weight, 150 lbs. per cubic foot. Composed of silica, 93 per cent. ; carbonate of lime, 2 per cent. ; iron and alumina, 4.5 per cent.

Bramley Fall.—A fine even-grained and strong stone, much used for docks, bridges, quays, and pavings. Can be had up to the largest sizes. Weight per cubic foot, 160 lbs.

Hayshaw.—A close-grained stone, nearly white. Is useful for all ordinary building purposes, and takes a good arris.

Longwood Edge.—A good average stone of a light brownish colour. To be had in good sized blocks. Is heavy and weathers well.

Meanwood.—A stone of average quality of a rather coarse grain. A light brown in colour. To be had in large blocks. Suitable for heavy work. Weight, about 140 lbs. per cubic foot.

Park Spring, Leeds.—A good even-grained stone of a light brown colour. In much request in the district for all building work. Is very suitable also for steps, thresholds, landings, copings, etc. Good weathering qualities. Weight, about 150 lbs. per cubic foot.

Scotgate Ash. (near Pateley Bridge).—There are several varieties of this stone, contingent on the position of the various beds in the quarries. The texture is fine grained and very even and compact. It stands very heavy pressures. In colour it is of a light brown. Suitable for steps, landings, copings, etc. Weight, 160 lbs. per cubic foot. Resistance to crushing, 740 tons per square foot.

Permian.—The only sandstones of any known value in this formation are found at Newbiggen in Cumberland, and one or two other quarries in the valley of the Eden. The stone is a rich deep brownish red, of good even consistency, and free working. It is of good average weathering quality, if care be taken to set it on its natural bed. Weight about 140 lbs. per cubic foot.

Triassic, or New Red Sandstone.—This formation is mostly found, insomuch as it affects the question of building stones, along the western counties of England and the Welsh borders. The Keupar division usually provides the best and most durable qualities. It is, as a rule, easily worked, being of a uniform texture and of even grain, but is often not a very good weathering stone.

Billinge, Cheshire.—A very even-grained stone of good weathering properties. In colours, bluish grey and nearly white. Can be had in good sized blocks. Useful for all ordinary building work. Weight, about 140 lbs. per cubic foot.

Grinshill, Shropshire.—A fine-grained, easily worked stone. Colour, yellowish white (also red). Weight, about 142 lbs. per cubic foot.

Beggars Well, Staffordshire.—A fine stone of even grain and sound weathering quality. Very much used locally. Of a good red colour. Yields good large blocks. Weight, about 138 lbs. per cubic foot.

Hollington.—A good reliable stone, sound and durable, to be had in blocks up to 5 tons. Colour, nearly white (there is also a red variety). Weight, 133 lbs. per cubic foot.

Park Quarry.—A good serviceable building stone of a light grey colour. Is to be had in convenient blocks for general purposes. Weight, 125 lbs. per cubic foot.

Hadley, Worcestershire.—A very durable, compact, and sound building stone, easily worked and suitable for all ordinary building work. Weight, 135 lbs. per cubic foot.

Jurassic.—There are very few known quarries of this formation, the principal being near the vicinity of Whitby, the general characteristics of the stones of this formation being strength and toughness, and also of capability for fine work. Stones that have been exposed for many centuries to the ravages of weather and time have shown little or no marks of exposure beyond the growth of lichens on their faces, the tool marks of the mason remaining as clear at the present day as when they were first fixed *in situ.* Other stone, however, has given evidence of great decay in the course of time. It would be feasible, therefore, to premise that great care should be exercised in choosing the beds of the quarries for the stone required, and also as to the setting of the stones on their proper quarry beds. It has to be remembered that with certain stones it does not always follow that the plane of cleavage is the original bed. Undue pressure caused by upheavals or other convulsions of the underlying rocks sometimes create a plane of cleavage varying in angle with the natural bed of the stone, in accordance with the direction of the force exerted in the superincumbent mass. A much more sure guide to the true bedding than the natural cleavage is to be found in the way in which embedded fossils or shells lie in the stone. If it contains any of these at all they will always be found lying flat on the bedding.

The above remarks may be considered as applying generally not only to sandstones but to other sedimentary rocks.

Bolton Crag Moor.—This is a good weathering stone of a uniform nearly white colour. It is especially suitable for piers, sea walls, and other positions where durability and strength are required. It is also capable of fine work, for mouldings and ornamentation.

It can be procured in good large blocks. Weight, 150 lbs. per cubic foot.

Newton House.—This is a good general building stone, but rather hard to work, and more suitable for foundations and understructures. In colour it is a light brown. Weight, 128 lbs. per cubic foot.

Limestones

Limestones are mainly derived from the Devonian, Carboniferous, Permian, and Oölitic formations. They consist, as a rule, almost entirely of carbonate of lime, or of admixture of lime and magnesia. Some, however, contain a considerable proportion of magnesia, while there are others with varying percentages of silicates, and a little alumina and iron. Some have fossil remains of sufficient size to prevent their use for decorative work, but these are generally massive and durable, and thus useful for positions where strength is the principal requirement.

Devonian.—The limestones found in this formation are often crystalline, being metamorphosed rocks and true marbles, and as such are susceptible of a high degree of polish. The quarries of this class are mainly found in Devonshire, near Plymouth, Babbacombe, and Ipplepen, and also to the north of the county, as at Staverton.

In colour these marbles vary much, — black, grey russet, etc., being found, some varieties being veined with streaks of white, yellow, or other tints.

Carboniferous.—In general the limestones of this formation are hard and somewhat crystalline, in many instances containing the remains of sea-lilies, corals, and nautilus shells. Trilobites are rarely found. Marbles are found in various parts of the Midlands (chiefly Derbyshire) belonging to this formation. Among the more important quarries are the following:—

Tottenhoe, Bedford. — A limestone composed of an intimate admixture of carbonate of lime and clayey matter. It is of a dull white with a green tinge. Is a fair weathering stone if carefully chosen. Its weight is only 117 lbs. per cubic foot.

Hopton Wood, Derbyshire.—A fine crystalline limestone capable of taking a good polish. It is a nearly pure carbonate of lime, with shelly fragments and fossils of encrinites embedded within the mass. Colour, light grey. It is of good weathering quality. Constituents—carbonate of lime, 98.5 per cent. ; iron and alumina, a trace ; silica, 0.75 per cent. Weight, 160 lbs. per cubic foot. Crushing resistance, 455 tons per square foot.

Sutton, Bridgend, Glamorganshire.—A very crystalline and compact stone, capable of a good polish. Colour, light cream. Is a good sound weathering stone. Nearly pure carbonate of lime. Weight, 136 lbs. per cubic foot.

Penmon, Beaumaris.—A crystalline limestone of a close-grained texture, taking a high polish. There are two distinct beds of this stone, differing to some extent in their characteristics. They are very compact and durable, and of good weathering properties. Weight, 168 lbs. per cubic foot.

Permian.—To the Permian belong the Magnesian limestones or Dolomites. These stones are generally chemical precipitates, naturally deposited in ancient salt lakes. Their general characteristics are ease of working and compactness, the granulation being very even and small. One peculiarity of this stone is the presence of silica in varying proportions. The best stone is, however, that which attains the nearest equality between the carbonate of lime and magnesia.

The more compact and homogeneous in structure the more durable is the stone likely to be.

The best known quarries are here enumerated.

Beer.—A good ordinary building stone, not very crystalline and of a pleasing light brown colour. Can be procured in good sized blocks. Weight, about 132 lbs. per cubic foot. Crushing resistance, 155 tons per square foot.

Mansfield (*White*). — Is generally known under the term "Dolomite," owing to its composition. This stone is of good quality, and useful for general building purposes. Can be obtained in large blocks of good scantling. The constituents are as follows :—silica, 52 per cent. ; carbonate of magnesia, 18 per cent. ; carbonate of lime, 27 per cent. ; iron etc., about 1 per cent. Weight, 150 lbs. per cubic foot.

Mansfield (*Red*).—Generally similar in structure to the above, the colour being a pleasing brown with a rosy tinge. Its constituents vary somewhat from the white as follows:—silica, 50 per cent.; carbonate of magnesia, 16 per cent.; carbonate of lime, 27 per cent. ; iron, and clay, 3 per cent. Weight, 148 lbs. per cubic foot.

Bolsover.—A highly crystalline stone of compact and even texture. A good weathering stone. Can only be had in moderate sized blocks. This stone is more of the nature of the "true" dolomite than the Mansfields. In colour it is yellow. Its constituents are—carbonate of magnesia, 40 per cent. ; carbonate of lime, 51 per cent.; silica, 3.5 per cent.; iron, etc., 2 per cent. Weight per cubic foot, about 152 lbs.

Anston.—Somewhat crystalline although of a granular texture. This is a good building stone. It is, however, most useful for steps, landings, engine beds, and all heavy work. It can be procured in fairly large blocks. Colour, cream. Weight, 143 lbs. per cubic foot.

Brodsworth.—A very useful stone of a light brown colour. Weight, 134 lbs. per cubic foot.

Cadeby.—A somewhat friable stone, containing the carbonates of magnesia and lime. To be obtained in good sized blocks up to 4 feet thick. Colour, cream. Weight, 127 lbs. per cubic foot.

Huddlestone.—A slightly crystalline stone, useful for general building purposes. It is similar in its constituents to Cadeby. Colour, a light cream. Can be procured in large blocks. Weight, 138 lbs. per cubic foot. The proportions are—carbonate of magnesia, 41

per cent.; carbonate of lime, 54 per cent.; silica, 3 per cent.; iron, a small quantity.

Park Nook.—A good building stone of a light cream colour. Like many limestones, unless carefully selected it is apt to be attacked and to deteriorate under the influence of a smoky atmosphere or where much rain is prevalent. Is composed almost entirely of carbonates of magnesia and lime in the proportions of 42 per cent. of the former and 56 per cent. of the latter. Weight, 137 lbs. per cubic foot.

OÖLITES.—This class of limestone is very abundant in various parts of the country, more especially in the counties of Gloucester, Somerset, and Dorset; of the shelly variety in Northampton, Rutland, and Yorkshire; and of the coralline in Oxfordshire.

In general these stones are compacted of small rounded or granulated particles of calcareous material cemented together with carbonate of lime. Hence the term "Roestones" for the Bath and Gloucester varieties, in which these characteristics are prominent. In the Portland and Purbeck varieties shells of extinct organisms and fossil remains are freely interspersed throughout the mass. Some, such as Purbeck, have deposits that are capable of a fine polish, and are often classed under the head of marbles. Owing to the presence of clay in these stones the surface soon loses its polish, as the moisture of the atmosphere becomes absorbed in the material.

Campden Hill. — A slightly crystalline and fine-grained stone, cemented with carbonate of lime; a free working and good weather stone. Can be had in large blocks. Colour, rich cream. Weight per cubic foot, 140 lbs.

Painswick.—A sound durable stone of very even grain, of great utility for carving and general ornamentation. Weight, 140 lbs. per cubic foot.

Ancaster.—A fine-grained stone, sometimes slightly crystalline. A very useful building stone, working freely. Colour, a pleasing cream. Is composed of carbonate of lime, 96 per cent.; carbonate of magnesia, 2 per cent.; iron, 0.75 per cent.; alumina, 0.45 per cent. Weight, 145 lbs. per cubic foot. Crushing resistance, 228 tons per square foot.

Haydor.—Very similar to Ancaster, but is of a deeper colour. Care should be exercised in setting this stone on its proper quarry bed. Weight, about 134 lbs. per cubic foot.

Taynton.—A good workable stone of the shelly oölite variety, containing very small shells and fragments. Colour, brown. Weight, 134 lbs. per cubic foot.

Edithweston.—A fine-grained stone, easily worked when fresh from the quarry. Hardens on exposure to the weather. Is a valuable stone for general building purposes. Colour, dark cream. Constituents—carbonate of lime, 92 per cent.; carbonate of magnesia, 4 per cent.; iron, 0.1 per cent. Weight, 128 lbs. per cubic foot.

Barnack, Casterton, and Ketton.—Almost identical with the last named with respect to both quality, colour, and constituents, and from the same district.

Chilmark.—A siliceous limestone of the same series as the Portland. There are three or four beds in the quarries having somewhat different characteristics. The lowest is extremely hard and of great weight, often as much as 154 lbs. per cubic foot. In colour a light brown.

The next bed above is more freely worked and not so heavy. In colour it is a greenish brown. Weight, 135 lbs. per cubic foot. The upper beds are more distinctly oölitic, and are of a cream colour. Weight, per cubic foot, 135 lbs. The constituents of the first two are about as follows:—carbonate of lime, 80 per cent.; carbonate of magnesia, 4 per cent.; silica, 10 per cent.; iron and alumina, 2 per cent.

Doulting.—An easily worked stone of good building quality. To be had in good useful blocks. It is crystalline in structure, and of a light brown colour. Weight per cubic foot, 134 lbs. Constituents—carbonate of lime, 79 per cent.; carbonate of magnesia, 5 per cent.; silica, about 5 per cent.; iron and alumina, 8 per cent.

Portland.—This stone is denser than the average of oölites, thus giving it a durability in smoky or damp atmospheres not to be attained by other stones of the same category. In general its colour is a whitish brown.

The best beds in the quarries, and the only ones now commercially worked, are those termed "Whitbed," producing a hard, firm, well compacted stone of great durability and strength. There is a considerable difference in the quality and density of the same class of stone taken from different quarries, but these are now almost entirely in the hands of two large firms of high reputation, who rarely quarry and never send out unsound stone. The weight varies in the different quarries and beds, averaging from 142 to 148 lbs. per cubic foot. Composition—carbonate of lime, 95 per cent.; carbonate of magnesia, 1 per cent.; silica, 1 per cent.; iron and alumina, small proportions.

Bath.—There are several quarries of this stone, most of them possessing distinctive characteristics, both as to their weathering properties, working facilities, and their adaptability to different positions in buildings. Most are owned by the same great combination, whom it is best to trust, stating for what purposes the stone is required.

The centre of the industry is Box Hill, the principal quarries being as follows:—

Corsham Down.—An easily worked, compact, and even-grained stone of good weathering quality, which takes a good arris. Is a generally sound building stone. Colour, cream.

Monk's Park.—This stone has similar qualities to the Corsham Down, and is of fine grain and easily worked.

Corngrit.—A very strong and even-grained stone,

suitable for beds of columns, steps, engine beds, or positions where strength is required. It is not a good weathering stone, and is thus of more utility in internal situations. Presents considerable resistance to crushing. Colour, cream.

St. Aldhelm.—A sound even-grained building stone standing the weather well. Is not so fine as Corsham Down, but weathers better. In colour light brown.

Farleigh Down.—There are several beds of this stone. It is even grained, capable of a good arris, and is suitable for inside work. Not of value in exposed situations. Colour, cream.

Stoke Ground.—A sound even-grained stone, of use for general building purposes, and easy to work. Colour, light brown.

The general constituents of Bath stone are as follows, slightly varying in the various quarries:—carbonate of lime, 95 per cent.; carbonate of magnesia, 2.5 per cent.; iron and alumina, 1 per cent. Weight, from about 116 to 123 lbs. per cubic foot.

Wass, Yorkshire.—This stone is produced in two qualities, the soft and the hard. It appears to be a very good weathering stone, and is of even grain. In colour it is brown with black specks, probably of free carbon. Constituents—carbonate of lime cemented with lime and argillaceous matter. The soft stone weighs 142 and the hard 162 lbs. per cubic foot.

Granites

The next group to be dealt with is that of the igneous rocks. These are known as granites, syenites, porphyrys, etc.

Many of these rocks may be more clearly defined under the head of Plutonic rocks, having cooled under pressure at some depth from the surface of the earth, subsequent disturbance and upheavals forcing them to the surface as intrusive veins and masses.

Granites are made up of varying proportions of quartz, felspar, and mica in irregular grains or fragments. The quartz may be black, white, or grey. The felspar is of a crystalline nature, sometimes as potash felspar (orthoclase), and at others as soda felspar (oligoclase). The colours may be either yellow, pink, or white. The mica is usually of a grey colour, sometimes nearly black.

The proportions are more or less — felspar, 40 per cent.; quartz, 30 per cent.; and mica, 15 to 20 per cent. These quantities vary, increased proportions of quartz or mica being encountered in different types of the mineral.

A mineral somewhat akin to granite and termed syenite contains horneblende in place of quartz, together with potash felspar and mica; while most British granites contain all four constituents—quartz, felspar, horneblende and mica, and should more properly be called syenitic granites.

Gneiss.—This is a species of granite, but with the component materials in layers or foliated.

The best known and most generally useful granites are from the following quarries:—

Cheeswring, Cornwall.—This is a porphyritic stone of a light grey colour and fine grain, useful for heavy structures where great strength and durability are necessary. Weight, 165 lbs. per cubic foot.

Hay Tor.—A fine-grained stone of great durability. Blocks of any size can be obtained. Colour, blue or greyish blue. Weight, 165 lbs. per cubic foot.

Mount Sorel. — A rough durable stone of great strength. Colour, pink. It is syenitic in composition. Weight, about 164 lbs. per cubic foot.

Shap, Cumberland.—A fine crystalline stone of the porphyritic variety. Very tough and durable, and capable of a high polish. In colour red. Weight, 165 lbs. per cubic foot.

Rubislaw, Aberdeen.—This is a fine-grained granite of the syenitic variety. It takes a high polish, is almost indestructible, and is applicable to the finest work. In colour it is a bluish grey. Can be had in large blocks or lengths for columns up to 25 feet. Weight, about 167 lbs. per cubic foot.

Peterhead.—One of the finest granites in the British Isles, is most useful for ornamental and polished work, such as columns, pilasters, plinths, etc. Colour, a warm pink. Weight, 165 lbs. per cubic foot.

Isle of Mull. — This district furnishes a fine pink granite, to be had up to any size required. In composition it much resembles the Aberdeen granites. Weight, 164 lbs. per cubic foot.

Inverary, Argyleshire, supplies one of the hardest granites to be found. It is more of the nature of a porphyry than the Aberdeen varieties, and is much more difficult to work. Weight, 165 lbs. per cubic foot.

Ireland supplies several classes of good useful granites, some of them of a fine handsome type and pleasing colour. Amongst the best known quarries are those of Wicklow, Down, Carlow, Mayo, and Galway. The quarries at Dalkey, near Dublin, furnish a good stone. Weight, 169 lbs. per cubic foot.

Testing Stone

Stones depend much on the adhesive qualities of the material cementing their component parts. The strength of these cementing materials determines their resistance to crushing and also to the effects of weather. It is important, therefore, to select a stone of a not too friable nature, and one that presents a clean bright fracture when freshly broken, with the cementing material closely embracing the various constituents of the specimen.

Resistance to crushing. — The stone to be tested should be of a fairly large section, say 4 to 6-inch cubes. The weight should be applied evenly over the surface, and gradually increased.

Absorption.—Well dry the specimens and immerse them in water for a day or more. Weigh both before and after placing them in the water. The difference

will represent the amount the stone will have absorbed.

Soluble matter in stone. — The immersion of small chippings of the stone in water for several hours will serve as a test for the presence of alumina or other soluble matter therein. Should the water become cloudy on shaking the presence of deleterious substances may be presumed, and if the cloudiness be pronounced the stone should be rejected.

Frost.—For resistance to the action of frost a careful inspection of the exposed stone in the quarries will give a fair criterion whereon to rest one's judgment, or the examination of a building in which the stone in question has been exposed for some years is even more reliable.

Foul air.—For resistance to the action of the foul atmosphere of large towns, the treatment of the stone by immersion for some time in a weak solution of sulphuric acid in water will give some idea as to its power of resisting the action of sulphurous fumes, etc., in the air or charged in the rain.

Causes of Decay

The chemical changes that may be effected in the structure of a stone by means of moisture may cause deterioration in the following ways: The introduction of wet and subsequent frosty weather may tend to force off particles of the stone, due to the expansion of the water in its change to ice in the pores. This danger is greatly minimised by properly setting the stone on its natural bed, and by protecting the walls by undercutting the cornices, strings, etc., so as to throw collected moisture clear of the face of the building. It is therefore essential to know the absorbent qualities of the selected quarry before use. It may be safely asserted that in nearly all cases a non-absorbent stone, or one showing a very slight percentage of absorption in comparison to its weight, will be a good weathering material.

Many stones contain within themselves the elements of decomposition, only awaiting the introduction of some other chemical element to awaken the seeds of decay. In these cases the presence of soda, potash, oxides of irons, and many other salts and chemical compounds will, on the introduction of wet charged with carbonic acid gas, surphur, or ammonia (present in the air of most of our large towns), soon set up chemical reactions with the salts contained in the stone and cause consequent decay.

High winds are a source of destruction in the following manner: Air travelling at high velocities picks up in its passage particles of silica and other substances.

The impingement of these particles against the faces of the stone of a building, more especially the salient features, will exercise a grinding effect on the surface. This is especially noticeable in Tynemouth Priory and other buildings upon our seacoasts.

Lichens and other vegetable growths are also very destructive to stonework, especially in damp country districts.

There are other agents at work tending to the destruction of stone used in tidal work, but the more important in connection with ordinary buildings have been above named.

Preservation of Stone

Many methods for preserving stone have been experimented upon with varying success, some of the better know of which are the following:—

Painting the face of the stone either with boiled oil or oil colour. This method is in use in some of our large towns, and when properly done is certainly effective while it lasts. The objections to it are: Firstly, on the score of expense, as at least four coats are required to give a thoroughly sound skin to the material to be protected, the first and often the second coat also merely sinking in and filling up the pores. Secondly, on the score of durability it is not economical, as a renewal of the paint must be made every three or four years at the outside.

Paraffin in a liquid condition, or in solution in naphtha, has been tried in place of boiled oil and is a more lasting material, but it also has the objections of producing an unsightly greasy or glazed surface, likely to pick up dirt, etc. Soft soap and alum laid on one after another have their advocates, but are not permanent.

The best processes are undoubtedly those in which the applied material enters into chemical combination with the constituents of the stone. These materials are mostly based on the principle of digesting silica in some powerful solvent, such as caustic soda. The carbonates, if a limestone, enter into chemical combination with the silica, forming silicates of lime and magnesia, which have great resisting properties to weather.

To sum up the pros and cons with reference to this much vexed question,—it resolves itself into a repetition of the advice to the architect to avoid all such methods, and rely on a personal examination of the stone intended for the proposed building, and to ensure by direct knowledge and due care, together with a series of tests, that the stone is the best for the purpose, and from the very best bed in the quarry selected.

Finally, many of the tests, weights, etc., herein contained have been obtained from the quarry owners, and the writer has also personally inspected many of the quarries, and verified, where possible, the characteristics of the stones commented on.

CHAPTER XVII

THE THEORY OF ARCHES, VAULTS, AND BUTTRESSES

(*Contributed by* E. H. Hawkins)

Arches such as occur in smaller buildings generally have their thickness determined by rule, but for larger examples it is more satisfactory to determine their stability by graphic means.

Semicircular Arch (see Fig. 172).—Take, for example, a semicircular arch of 27 feet span and 1 foot 9 inches in depth, occurring in a wall 2 feet in thickness, and carrying masonry of that thickness up to a horizontal line XY, being such as might occur in a nave arcade. According to the old Gothic practice, the courses

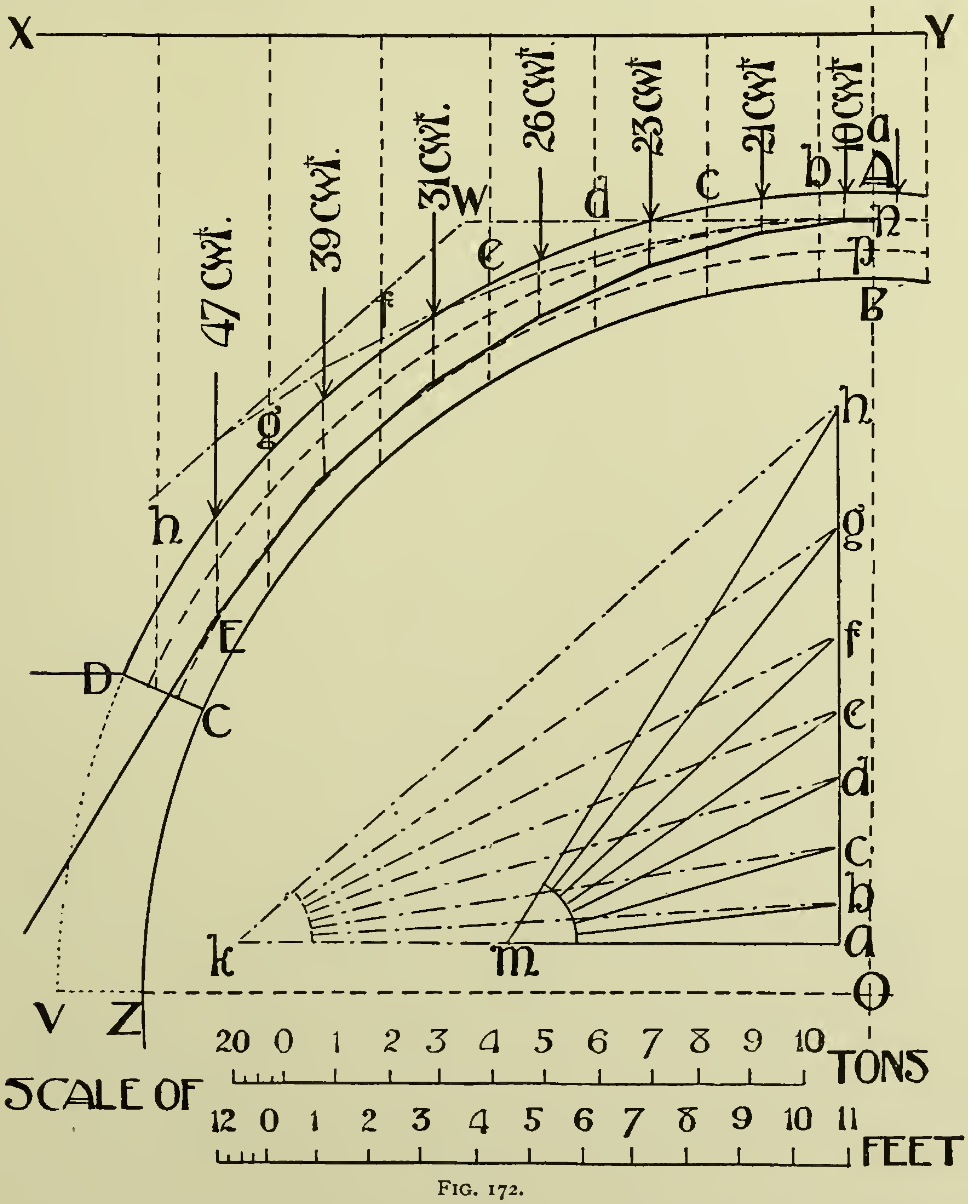
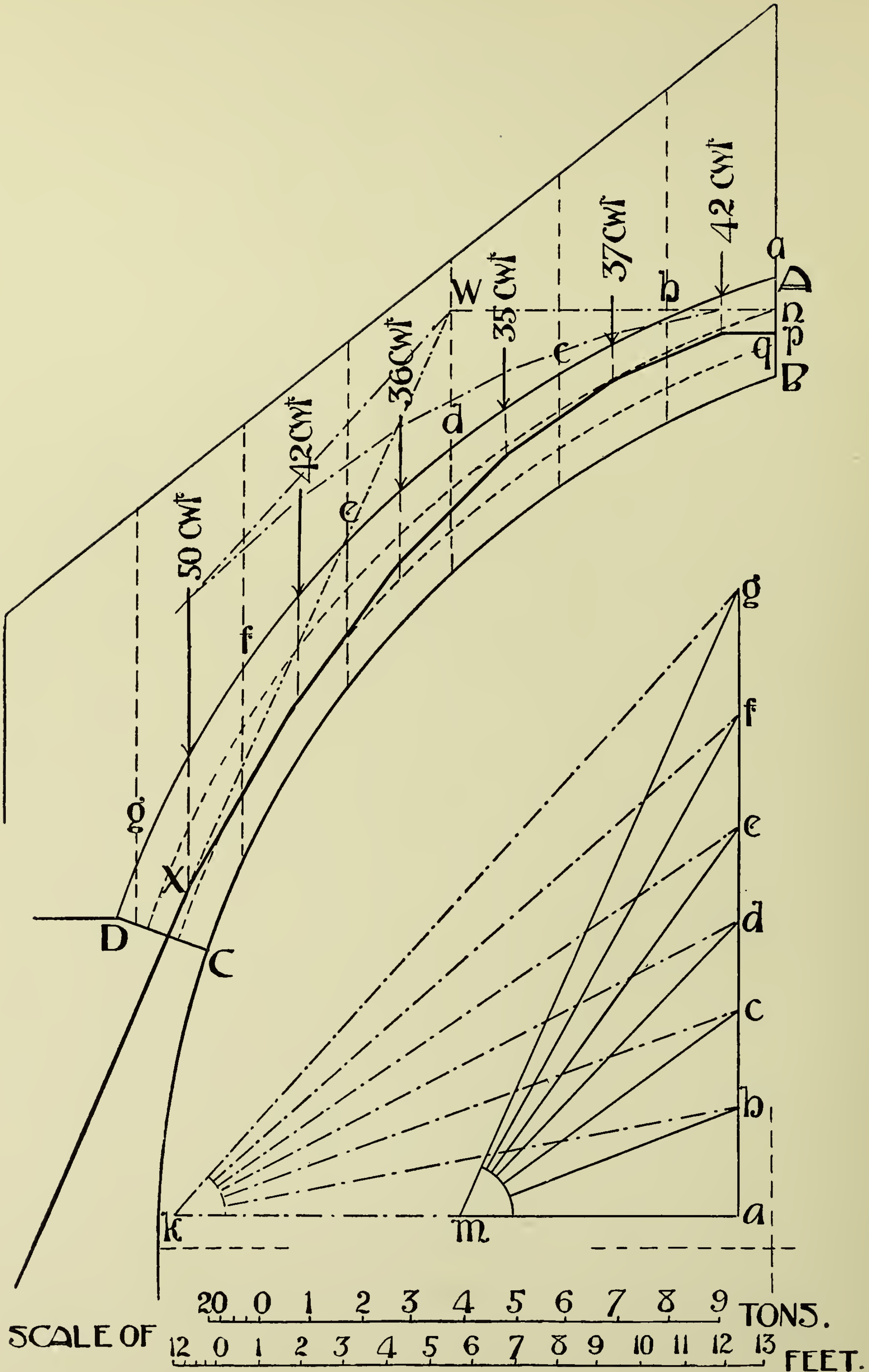


Fig. 172.



50 CWT
42 CWT
36 CWT
35 CWT
37 CWT
42 CWT
W
a
D
n
p
q
B
b
c
d
e
f
g
X
D
C
g
f
e
d
c
b
a
k
m
SCALE OF
20 0 1 2 3 4 5 6 7 8 9 TONS.
12 0 1 2 3 4 5 6 7 8 9 10 11 12 13 FEET.

Fig. 173.

were built horizontally for some height. As will be seen presently, this is theoretically correct, and in this case the actual arch is shown springing from a skew-back at DC. An arch is kept in equilibrium by the action of three forces, the thrust at the crown, the weight of the arch and its load, and the reaction of the abutments.

If an arch is symmetrically loaded the thrust at the crown must be horizontal, assuming that there is a vertical joint there, and not a keystone. At what point the thrust acts in AB (the depth of the arch ring) cannot be positively ascertained, and the theory regarding arches is therefore in a somewhat uncertain state ; but it is generally assumed to act somewhere within the centre third, this being necessary if stability is to be secured.

Method.—Mark off the centre third of arch at *n* and *p*. Take any number of equal parts on XY, and draw vertical lines downwards from the points obtained to meet the extrados at *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*.

Calculate the weights of the 4-sided figures so obtained, and draw vertical lines where the line of action of each acts on the arch, *i.e.* centrally between *a* and *b*, *b* and *c*, *c* and *d*, etc.

Suppose the thrust at crown to act at the point *n*. Through *n* produce the horizontal thrust to meet the line of action of the first load between *a* and *b*, and from the point where they intersect draw the resultant parallel to *kb*, as shown on the dotted trial diagram to meet the next line of action between *b* and *c* ; and so proceed till you reach the line of action of the last and greatest load between *g* and *h*. Produce the line obtained (which will be parallel to *kh*) backwards till it cuts a horizontal line drawn from *n* at W ; then W will be the centre of gravity of all the loads. Join W to the point E where the load between *h* and *g* impinges upon the inner line of the central third of the arch ring, and from *h* draw a line *hm* parallel to WE, cutting *ak* at *m*. Join *am*, *bm*, *cm*, *dm*, *em*, *fm*, *gm*, and *hm*. Now, starting from *n*, draw the polygon *n*EW, with its lower sides parallel to *am*, *bm*, etc.

The lower sides will then form the line of pressure. If this line is wholly within the centre third, then the arch will be stable. If not, the arch must be thickened or its form altered until it is possible to draw a line wholly within by the above method.

In this instance, if the arch rose from the springing VZ, the line of pressure would run outside, and rotation would tend to take place round V. It becomes, therefore, theoretically necessary to form the Gothic *tas de charge*, making DC the springing.

N.B.—In practice sufficient backing would effectually prevent any rotation of V, so that a complete semicircular arch might be employed.

Pointed Arch.—To determine the stability of a pointed arch of 29 feet span and 2 feet 3 inches in depth, in a wall 2 feet in thickness which terminates in a gable end (see Fig. 173). This example is similar in working to the last, but it is found on trial that the

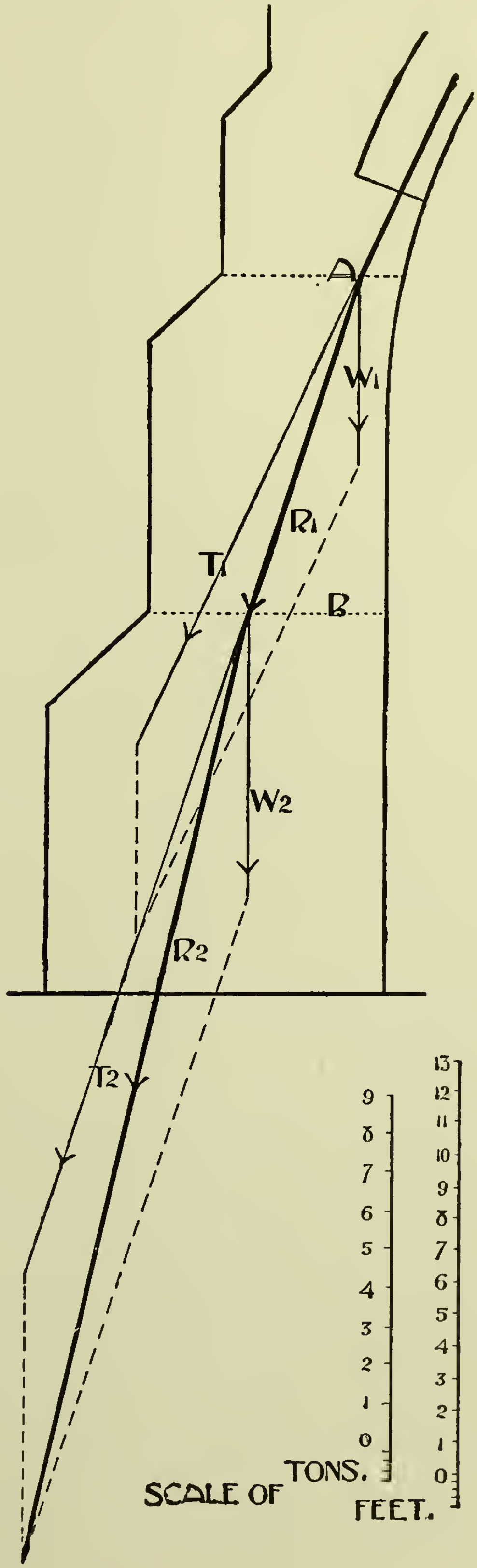


Fig. 174.

line of pressure, if started as before from *n*, passes quickly outside the centre third. A point *q* is therefore taken nearer *p*, when it will be found to work satisfactorily.

The resultant thrust at X is represented completely in magnitude, line of action, and direction by *gm* on the diagram.

It is required to find the buttress needed to counteract this thrust (Fig. 174),—that is, to provide sufficient abutment to keep the resultant within the middle third of the masonry throughout. The thrust T_1, which is equal to the thrust at X obtained from Fig. 173, but drawn to a smaller scale for purposes of book illustration, combined with weight W_1 (of the masonry above a horizontal line at A), produces a resultant R_1.

Resultant R_1 in its turn, combined with W_2 (weight of masonry between horizontal lines at A and B), produces resultant R_2; and the buttress shown keeps these lines within the centre third as required.

To Determine the Stresses in a Quadrapartite Pointed Vault.—The line of pressure in both diagonal and transverse ribs is found as shown in Fig. 172, with the exception that, as in this case the actual joints are shown, the line of pressure need only pass within the centre third where it crossed them.

The weights are taken to act on centre of extrados of each voussoir, and, being graphically proportional to the amount of severy that they respectively carry, the lines *gt* and *pa* then represent the thrusts in the transverse and diagonal ribs respectively, which thrusts may be taken as meeting at a point A on plan.

The thrusts in the two diagonals are equal, and meet at an angle of 90 degrees at a point A_1 on elevation, vertically over A on plan, producing the resultant shown, with the same line of action and direction on elevation as the diagonal ribs themselves, as represented by the line A_1X. The thrust of the transverse rib is represented by A_1Y, and meets A_1X at A_1, a point vertically over A on plan, to produce the total resultant thrust A_1Z.

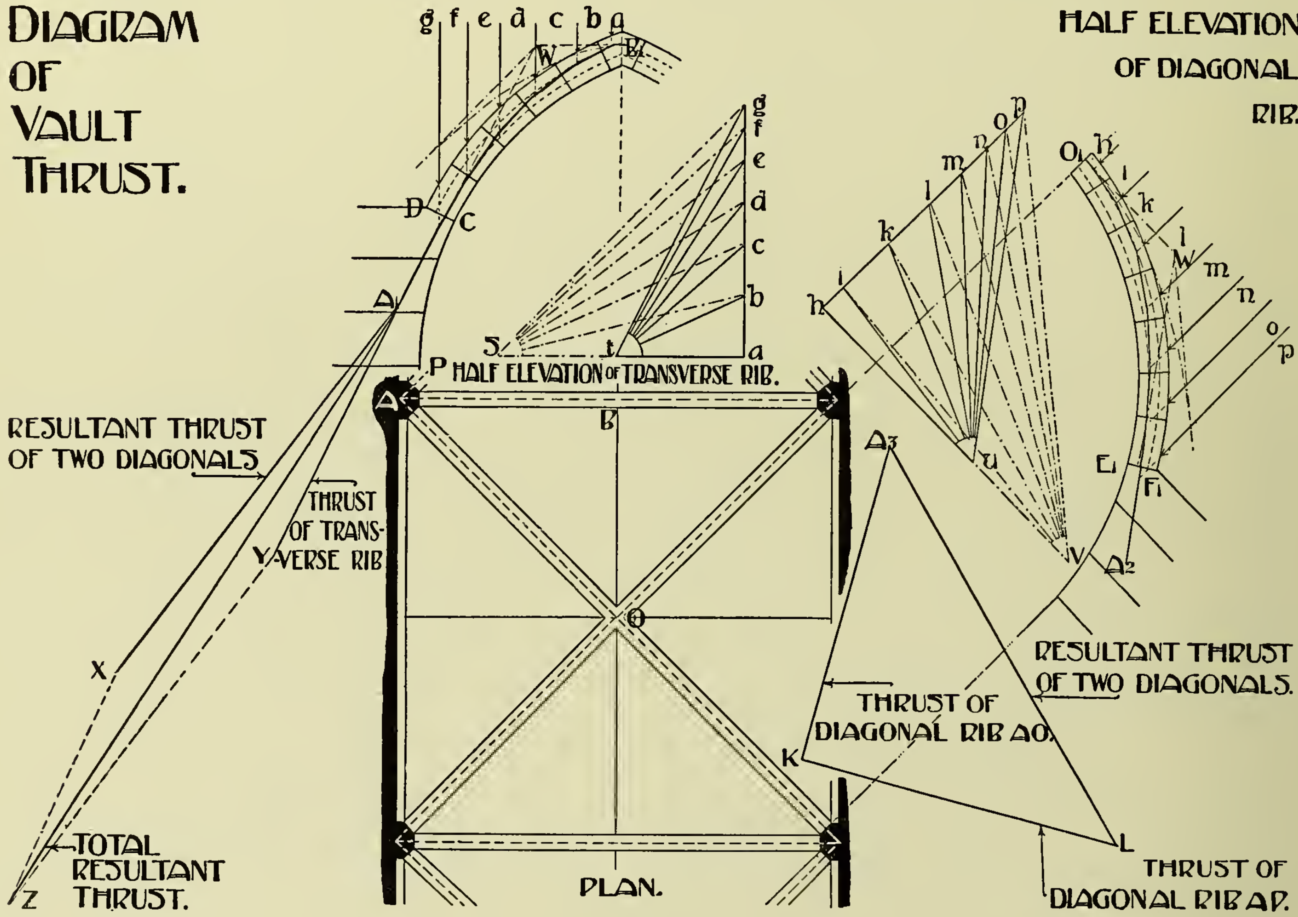


Fig. 175.

PART III

THE DUTIES OF CLERKS OF WORKS

(*Reprinted from* The Building News)

CHAPTER I

EDUCATION—LETTERS AND REPORTS

There are few more difficult positions to fill in connection with buildings than that of a Clerk of Works, yet there are none about which so little information is to be obtained, either in books or in articles contributed to our own columns or to those of our contemporaries. To a certain extent the position is more important even than that of the Architect, as it is the Clerk of Works who is directly responsible for good materials and good workmanship. He is, in fact, the direct descendant of the Architect, or chief builder, of former days, who doubtless designed and controlled a building himself from commencement to completion, scarcely ever leaving it, but following it day by day, and seeing that its every detail was to his perfect satisfaction. At the present time he occupies a midway position between Architect, employer, and Contractor, and, as buildings become more complex, so do his duties become more difficult of performance.

Generally selected by the Architect, and responsible immediately to him, he is paid by the building owner, sometimes directly, sometimes through the Architect. In the case of municipal work, or that undertaken by any incorporated body, it is usually the building owner who pays direct; but the private individual rarely cares to be troubled with small weekly disbursements. With such a building owner the Architect hands the Clerk of Works his salary, and again charges it against the owner from time to time as it accumulates, say, for one month, or for three. Under this peculiar arrangement of joint appointment, or rather of appointment by one man and payment by another, it is not always easy, in the absence of special arrangement, to say to whom the Clerk of Works is most responsible, the Architect or the employer, or from whom in case of need he must accept notice of dismissal. At the outset of his employment there ought to be a clear understanding upon these points; but even at best the position becomes an exceedingly difficult one under some circumstances. So long as all is above board, as it is in the vast majority of cases, no trouble arises. The Architect, as the owner's agent, stands in his place and possesses full power. But it has occasionally been known for a Clerk of Works to condemn bad work, and for the Architect subsequently to disallow his action—not once, but again and again, where large sums are involved, until the Clerk of Works seriously doubts the Architect's action being *bonâ fide*,—for until such a doubt arises the Architect's decision is undoubtedly final. In such a case it has—rarely, but now and again—been the Clerk of Works' duty to report the matter to the employer by whom he has been paid, and trouble has naturally followed. Without advocating the adoption of this course except as an extreme measure under very serious circumstances, enough has been said to show how delicate the position may become.

Except in such a rare case as has just been referred to the Clerk of Works' position is legally that of the Architect's representative on the works. The clause in which it is defined in the R.I.B.A. Conditions of Contract is as follows:—"The Clerk of Works shall be considered to act solely as inspector and under the Architect, and the Contractor shall afford him every facility for examining the works and materials." This does not give him the right to so far trade upon his position as to actually interfere, on his own responsibility, with the planning aud design of the building committed to his charge. It is, in fact, his duty to see that the drawings and specification are complied with in every possible respect, and to report to the Architect whenever compliance is not possible, acting on his own initiative, however, when emergencies arise, as they sometimes do in the most unexpected way. Within these limits he has authority to order *necessary*

extras, and at all times towards the Builder he occupies the place of overlooker, against whose decision there is little appeal on matters of construction, workmanship, and quality of goods supplied. With the individual workmen employed he has not much to do, his dealings being much more with the Foreman, to whom alone he should make his complaints and enforce his orders, though as the Architect's agent he has the power, if necessary, of insisting upon the dismissal of any particular workman, either for incapacity or misbehaviour.

If will be seen that these powers and responsible duties involve the close attention of a capable man, if a building of even a moderate size is to be thoroughly overlooked. He must be on the works when the men arrive in the morning, if only to check such practices as the using up of stale mortar, and he must be there almost constantly, watching every cartload of material as it is brought upon the site, inspccting it and rejecting it immediately if unsuitable, and seeing in such a case that it is removed at once. He must watch the workmen throughout the day, seeing that everything is performed in a thoroughly sound manner ; and he must occasionally visit the Contractor's workshop, so as to supervise the joinery which is there being prepared long in advance of the time when it will be required to be put into position. Where deviations occur from the original intention as expressed in drawings and specification he must make careful notes of these, taking measurements in all instances where the work is subsequently to be hidden. He must keep regular diaries and records of everything that occurs, and must report regularly (preferably on forms supplied for the purpose) as to what is happening, calling attention in good time to any probable difficulties which he may foresee. He must, moreover, have the power of insistence, to ensure that defects really are remedied, and not merely hidden up and forgotten.

The class of man suited for such work as this is somewhat exceptional. Above all things, a Clerk of Works must have a most intimate knowledge of building operations. He must be a practical man among practical men ; but beyond this he should have studied sufficiently to know a good deal more than the majority of those placed under him. Too young a man has not sufficient authority for such a post, nor would he probably have sufficient knowledge. Absolute honesty is, of course, essential ; but this, one is glad to say, is not difficult to find, and the Clerk of Works who will accept bribes from the builder or the manufacturer to induce him to pass imperfect work is decidedly the exception. Possibly the best fitted for such a post is the man who has been trained at one of the principal building trades, such as that of carpenter or mason, and who has attended good technical schools and kept his eyes open on the works, so as to obtain good working knowledge of all the other trades connected with building operations. Such a man has probably, in a Builder's employment, been raised to the position of Foreman, first in his own trade, and subsequently over all the work connected with a building. Knowing in this capacity everything from the Builder's standpoint, he is often perfectly fitted to supervise from the Architect's standpoint. He needs to be self-contained, able to speak his mind, and also able to control himself, perfectly firm, sober, and consistent ; but perhaps his greatest qualification is that of method, so that he may have records of all that occurs available for production whenever they may be needed.

There can be few worse Clerks of Works than he who makes a pal of the Foreman ; and while he who is always appealing to the Architect upon every little question will soon be voted a nuisance, and is not likely to be employed twice in succession by the same man, it is almost as bad for him to take too much upon his shoulders, and, when confronted by a difficulty, to order it to be got over by some method which will alter the design or increase the cost without consulting his superior first.

In his intercourse with the building owner reticence is especially necessary, else it is possible for him to cause a good deal of trouble. He must remember that it is the Architect to whom his reports are primarily to be made, and whom he must consult in cases of difficulty, the employer having no power to order deviations or extras. A fidgety employer will give both the Foreman and the Clerk of Works a good deal of trouble ; but while he must be treated respectfully and with attention, it is always well to be careful as to what is said. It is not even advisable to let him know in all cases what it has been necessary to condemn, for much less friction arises if bad work is dealt with directly than if a third person is introduced.

A moderately good education is, of course, a necessity ; but there are few men who are at all likely to be appointed to such a position who cannot at least write a readable report and make ordinary calculations. A good knowledge of solid geometry is also exceedingly valuable, if not essential, for the proper reading of the drawings which are supplied, and for making additional ones if it be necessary ; though this rarely comes within the actual scope of a Clerk of Works' duties. An acquaintance with ordinary surveying of a simple kind is useful in order to secure proper setting out and the placing of a building in its right position on a site, and he must be capable of using a dumpy level. A knowledge of materials, their method of mixing, and the tests to be applied to them, will have been obtained by practical experience to a large extent ; but it is much better if this has been supplemented by a course at a good technical school or college, for it must inevitably happen that from time to time new materials are introduced, or those which are new to the individual man, and he must be able to discriminate at once between the good and the bad, whether he has seen them before or not, or, at any rate he must

be capable of placing his hand upon the necessary information without undue delay.

One of the first things that a Clerk of Works has to do when he takes up his appointment is to see that he is provided with a proper office, and the necessary appliances to enable him to conduct his work in tolerable ease and comfort. There is generally a clause at the commencement of the specification describing the office, and how it should be fitted; but even a more general clause carries with it of necessity that it should be so placed as to give him access at all times to all parts of the work; that it should be sufficiently well constructed to be wind and weather proof; that it should contain a stove for warming, and be supplied with a stool and a desk having drawers, all fitted with locks, and large enough to contain drawings and papers. A 5-feet rule is also generally provided by the Contractor, and upon large works it is reasonable also to insist upon having the sole use of a level and staff, though upon smaller works these are shared with the Foreman, and occasionally are not considered to be necessary at all. The Clerk of Works, as a rule, provides his own drawing instruments and 2-feet rule; but he may very well call upon the Builder for a drawing-board, T-square, and set-square, and for ink and ordinary writing-paper. Drawing-paper, if needed, he more generally purchases and charges to the Architect, while report forms and diary are usually supplied to him. Petty expenses, such as those incurred for stamps and travelling, are also charged against the Architect; but fuel for his fire must be provided by the Contractor, and the Clerk of Works should see that his office is always kept clean and warm for his use, so far as the circumstances of the works will permit.

A good form of office is that illustrated herewith in Fig. 176. The internal dimensions should be about 12 by 8 feet, with the door at one end and a fireplace connected to a brick chimney at the other. There should be a writing desk or drawing table along the whole of one side, with drawers underneath and a large window over for drawing purposes, so placed as to enable the Clerk of Works to watch the building from his office. Glass panels in the door are also useful for this purpose. There should be a lavatory basin behind the door, with a waste discharging outside, and with a slate or marble slab adjoining for the purpose of mixing up sample briquettes of cement, etc., for testing. A cupboard against the wall opposite to the desk is also needed for storing various requisites, while a drawing-board, stool, and T-square should be provided, besides a couple of hat and coat hooks, coal-box, shovel, and thermometer. Such an office is generally built of studding, match-boarded inside, and weather-boarded externally, tarred felt being used as the roofing material. There are, however, no fixed rules for this. Stoves often take the place of fireplaces, and occasionally the office has to be of a portable character, and erected upon the scaffolding. It ought to be provided with a boarded floor.

A good supply of stationery and of all essentials should be laid in at the commencement, but not an over-supply; while such things as colours, which may or may not be needed, had better not be obtained until they are actually required. There should, however, be a fair stock of pencils; some of these should be of

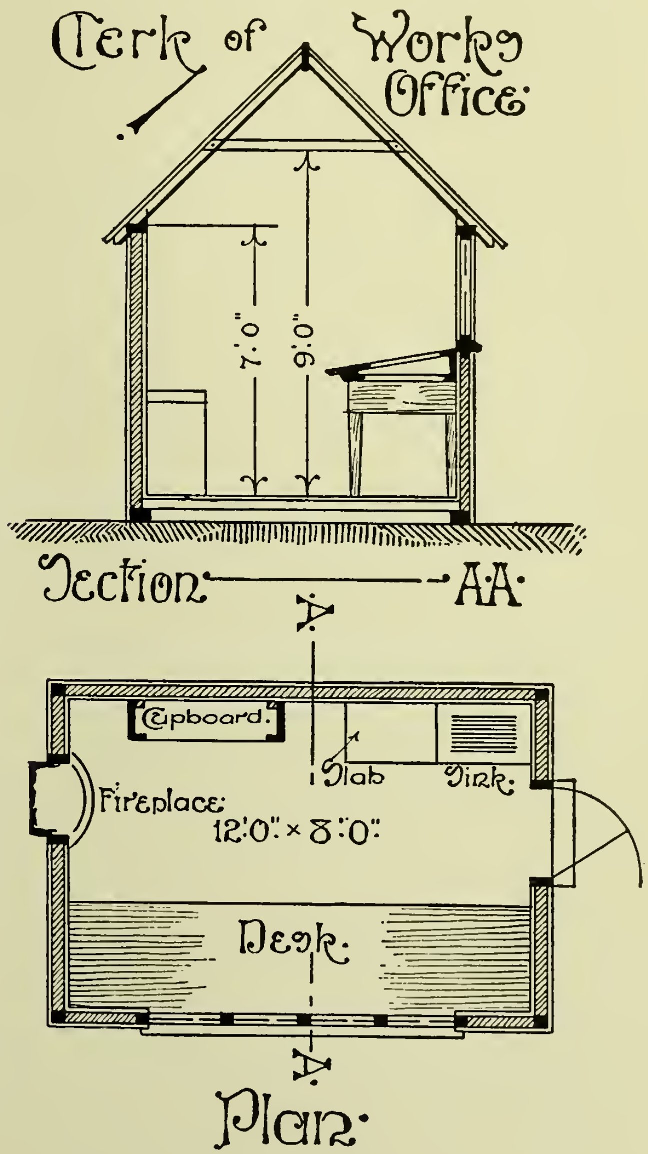


Fig. 176.

the carpenter type, and others should be of blue chalk for marking rejected materials.

So many things which occur during the course of building affect the eventual price, and so many of the Clerk of Works' decisions are liable to be called in question at a subsequent date, that it is of the very utmost importance for him to keep his records in perfect order. In fact, the orderliness should be such that he is not only able to greatly assist the surveyor in finally settling up the accounts, but he should be

able at any moment to place perfect records of what has occurred in the hands of the Architect or his representative. For this three things are requisite. He must keep the letters, both those he writes and those he receives, in such a way that any one of them can be found at any time. He must make careful diary entries of everything that occurs, and he must render weekly accounts according to some recognised form.

With regard to the letters, those which are received ought each day to be endorsed and put in their proper places. Probably the best method of doing this, where the number of letters received is small, as it must be in the case of a Clerk of Works, is to fold each letter lengthwise in two, so that the written matter is inside, and to write at one end of the long folded strip thus obtained the name of the person from whom it is received, putting the surname first and then the initials, and underneath the date which the letters bear. Thus —Abbott, B. C.,

3.12.05.

The letters when endorsed should be put into their proper places in a large bundle or bundles—usually a single bundle serves at the commencement—all the letters from Abbott, B. C., being placed at the commencement of the bundle and followed by those from Adamson, H. K., and Bishop, T. G., in alphabetical sequence, while those received from Abbott are themselves kept in date order. As the bundle grows it may be separated into smaller bundles, and it may be necessary eventually to have a bundle for each letter of the alphabet, though this is very rare when the letters are so few as are generally necessary for a Clerk of Works to write or receive. The bundles can be kept in a drawer, or preferably in the pigeon-hole of a cupboard, provided that the pigeon-hole be large enough ; and, of course, the cupboard in which they are preserved should be under lock and key. Letters which are written by the Clerk of Works must, as a matter of absolute necessity, all be copied, an ordinary letter-book being the best means of doing this. Duplicating books are sometimes provided, and are handy, inasmuch as no copying-press is necessary, and the resulting letters, although not having a sufficiently good appearance for issue from an Architect's office, are quite good enough for most of the purposes for which they are needed by a Clerk of Works. Whatever system is adopted it is, of course, essential that there should be an index to the book, and that this should be kept up from day to day.

This work, as well as the endorsing of the letters received, can be done at the same time that the diary entries are made at the end of the day ; but it is not always wise to leave these latter entries even for a few hours. Thus, although the general habit should be acquired of completing all entries and notes at the conclusion of each day's work, and seeing that the records are perfect up to that time, yet everything should be noted immediately that it occurs, if omissions and mistakes are to be avoided. The diary must necessarily be rather large, with ample space for each day's entries, as these are occasionally bulky. The greater part of the space devoted to each day has to be given up to miscellaneous entries, everything being recorded briefly but exactly, including the times of entering the works and of leaving, with particular notes upon inspections made to workshops or to specialists, with brief records of what occurs. In the same way the visits of the Architect or his representatives, or of the owner, or any member of a building committee should be noted, as well as the amount and quality of all materials brought on to the site, and whether they are accepted or rejected, with the reasons for rejection, and any important conferences with the Builder or Foreman. In fact, every little occurrence during the whole progress of the works should find its record in the diary, in many cases as a mere reference to notes made in full in a measuring book or on plans ; but still the reference should be there to serve as a guide in the future, and form a perfect history of all that has occurred.

These miscellaneous notes ought, as has just been said, to be made at the earliest possible moment after the occurrences have taken place, in order that there may be no chance of forgetfulness, and each day's entries ought to be signed. But besides these general notes there are certain others which of necessity occur day by day, and these may very well be entered in tabular form at the bottom of the space allocated to each day. These include a report as to the weather, and delay occasioned thereby, if any, and the number of workmen employed, preferably given separately for each trade, if the information can be obtained from the foreman, as it ought to be, and the hours at which the workmen started and left off. It is a very common thing to include among the general entries the results of tests of materials ; but where there is some special material which has to be tested frequently, as is the case where Portland cement is largely used, there ought to be a separate test record kept in tabular form, and the columns should be headed somewhat as follows : — Number or description of sample ; date received ; received from ; made into briquette, date and hour ; removed from mould and put in water, date and hour ; removed from water and put into testing-machine, date and hour ; result of test ; pat made for boiling, date and size ; description and result of test. If any other than the tensile and boiling tests are applied they may be similarly tabulated, it being well understood that all cement tests are carried out under uniform conditions.

The orderliness which is thus started with the letters and the diary can be consistently maintained throughout everything. The cement samples should be kept in tins which bear the number and date of receipt corresponding with the record, and the briquettes and boiling samples should be similarly numbered. If only one briquette

and one boiling pat be taken from each sample the number of the sample is all that need appear ; but if several be made from each sample they should be distinguished as *a*, *b*, *c*, etc., and so referred to on the record. After the briquettes and pats have been tested they should be retained on the shelves in close proximity with the tin containing the original samples, or so much as is left of them.

In the same way all drawings received from the Architect should be numbered immediately upon receipt, and a tabulated record should be kept showing in different columns the number of the drawing, its title, its scale, and the date of its receipt ; and further columns may become necessary to denote when tracings were made, and what became of these tracings, though, as a general rule, a single column for remarks is sufficient for this purpose, any tracings being given fresh numbers and entered separately in the record. So far as may be the drawings should be kept in their number sequence in the drawers provided for them, in order that they may be turned up whenever they are wanted ; but to do this requires a capacity for orderliness which is not possessed by everybody.

The same methodical habit which is essential in keeping diary and letters is equally necessary in making periodical reports. As a general rule these are rendered weekly ; but in some instances, particularly when dealing with public bodies whose committees meet at longer intervals, it is only necessary to make fortnightly, or even monthly, returns, though in such a case there is considerable chance of the general thread being lost, and of items being forgotten.

It must be borne in mind that a report is quite a different thing from a letter upon some special matter. This is necessarily written at the moment when the occasion for it arises, and as often as not there is no need for any reference to be made to it in the report, which should be short, concise, and business-like, preferably in tabular form, the information contained in it being taken from the diary. The form used in H.M. Office of Works is printed above by the courtesy of Sir Henry Tanner, who, in his accompanying letter, says that some of the particulars are entered at headquarters after receipt from the Clerk of Works.

H.M. OFFICE OF WORKS.

BUILDING..

Clerk of Works' Report for Week ending..

No. of Men.	Trades.	State of the Works.
....	Excavators	....
....	Bricklayers	....
....	Masons..............................	....
....	Carpenters and Joiners..........	....
....	Slaters	....
....	Plumbers	....
....	Plasterers..............................	....
....	Smiths..............................	....
....	Painters and Glaziers	....
....	Labourers..............................	....
(Total)		Value of old materials removed from site to date £
	Time lost, but *allowed by Conditions.*	Selling value of plant. £ — Date of completion. — Gross Contract Amount £............ Minimum Advance ...... £............

	Days.		£ s. d.	£ s. d.
Brought forward				
Monday..................	....	To amount of valuation brought forward from last Report	....	....
Tuesday..................	....	Value of work done during the week............................	....	....
Wednesday..............	....			
Thursday	....	Take forward........................£	....	....
Friday..................	....	Value of unused materials on the site............................	....	£............
Saturday	....			
	....	Total....................	....	£............
Total (to take forward)	....	Gross Amount of Certificates....................	....	£............
		....(Clerk of Works)		

(*N.B.*—Any further particulars to be given on back.)

This form would not necessarily apply in all cases, and in private work it would probably be much better for no entries to appear upon it other than are made by him who signs it, as its validity might otherwise be called in question should it ever have to be produced in a court of law. It ought also to bear its date. Values are very rarely entered by the Clerk of Works, but are reserved for the Surveyor or Architect. For use in a private office it might be advantageous to divide such a report into two parts, one of which should be signed by

the Clerk of Works and the other by the Surveyor, if one be employed. The following is a form of some general applicability, but it would probably have to be varied under special circumstances :—

Clerk of Works' Report for week ending............

No. Building................

Workmen employed. A. B. C., Architect.

Trade.	No.	Weather	Time lost, but allowed by Conditions.	
Excavators......	......	Monday..........	Brought forward	Days.
Bricklayers.....	......	Tuesday.........		......
Masons...........	......	Wednesday.....	Monday..........	......
Carpenters and Joiners ..	......	Thursday........	Tuesday..........	......
Slaters...........	......	Friday............	Wednesday.....	......
Plumbers........	......	Saturday.........	Thursday	......
Plasterers.......	......	Sunday...........	Friday............	......
Painters	......		Saturday..........	......
Labourers	......	Drawings required	Total	
Smiths	......		(To take forward)	
		Drawings received (The numbers only need be stated)		

Day Work.—The Clerk of the Works is requested to get from the Contractor every week an account for any day work that may have been done during the previous week. Each account should state the names of the workmen engaged, and the number of hours occupied, describe the work done, be signed by the Foremen and Clerk of Works, and sent up without delay to the Architect. Such day-work accounts are not necessarily vouchers for extras.

Present State of Works.

General Report on materials and workmanship, giving reasons for any rejections in detail.

It is frequently advisable to illustrate such a report by sketches showing the present position of the works, and this can best be done by having the ground-floor plan printed on the back of the form, so that the heights above a given datum at the various points may be figured on it in red by the Clerk of Works, together with any notes or reference letters to which he may draw attention in the actual report. Occasionally, though unfortunately somewhat too rarely, a Clerk of Works will be met with who is accustomed to photography, and so can supply the Architect with photographic prints showing the position of affairs from time to time.

It is probable that in most cases the reports take a colloquial form, and are written somewhat as letters, of which the following may be taken as examples :—

Report on Samples of Materials Delivered on to Works.

Dear Sir,—I beg to inform you that samples of facing bricks have been delivered from Messrs. A, B, and C, and to report thereon as follows :—I find the first sample A to be of very poor quality, and, in my opinion, totally unsuited for the class of work to be done, being of a porous nature and likely to crumble and lose their face in the exposed position in which this brick is to be used. The sample from firm B is a better brick, being very hard and well burnt, and well suited for the purpose ; but the colour is so irregular that it would not present as pleasing an appearance as the elevation demands. The sample from firm C is, in my opinion, the best brick of the three, being reasonably hard, square and straight, and even in colour, and I should recommend this one as suitable for use. It would be well to come to an early decision in the matter, as I understand from the merchants' agents that it may take some weeks to deliver the large number required, if the order is not placed at once, and it is very desirable to obtain them as nearly as possible from the kilns in one burning, to ensure evenness of colour, etc. Awaiting your instructions,—I am, Sir, your obedient servant, W. N.

Dear Sir,—In accordance with your instructions I have now tested the samples of cement you sent me, marked A, B, C. After seven days' immersion in water five briquettes from sample A broke when subjected to an average tensile strain of 420 lbs., five briquettes from sample B broke at 410 lbs., and five from C, an average of 382 lbs. I have also tested each sample for expansion in glass tubes for the same time, and find that sample A broke two out of three tubes. B showed no movement whatever, and C burst one tube on the sixth day. In my opinion sample B is the best cement, and I would recommend it for use in this contract. Awaiting your instruction,—Your obedient servant,

W. N.

To the Chairman and Members of the Building Committee.

Gentlemen,—I beg herewith to hand you my monthly report.—The work since my last report has been somewhat delayed by the wet weather ; but good progress has been made with the Sanitary block on the south-west side, which was roofed and covered in before the bad weather came on. The whole of the brickwork has been now raised to first-floor level with the exception of the portion over the main entrance, which has been delayed by the non-arrival of the large steel girders that carry the main wall. I have written the engineers respecting this delay, and they inform me that they will expedite delivery, and hope to deliver the necessary girders early next week.

The masons' work is well in hand, and I hope that the lost time will soon be made up when the girders come to hand.

I have had considerable trouble with the joinery for Sanitary block, and have had to reject a large number

of oak frames which, in my opinion, were not up to the specification.

I am sending you samples of the glazed bricks required for the walls of lavatories, and would recommend the sample marked A, as I find it has the best glaze, and is more even for colour, thickness, and length than the others—these last two qualities being very important for glazed brickwork. I received a letter from your clerk, of the 7th inst., requesting me to include in my monthly report my recommendations respecting painting the plastered walls in the lobbies and up the staircase. It would be very unwise, in my opinion, to paint these walls unless the plaster used is Keen's cement trowelled smooth. If Keen's is used a thoroughly satisfactory job can be obtained, but the extra cost will be considerable—approximately £80. It would be necessary, if Keen's is used, to instantly follow the finishing of the plastering with the first coat of paint; so that this matter should be settled at once, or delay may occur.

The section of drains from the Sanitary block has now been completed, and is perfectly satisfactory, having been duly passed by the local sanitary authorities. The section from the main sewer will be commenced next month, and taken up to the M.H. at boundary of the site, and left there until the main building is more advanced.—I am, Gentlemen, your obedient servant,

W. N.

These are all very well, provided that the Clerk of Works has the gift of literary composition; if not, they fail utterly, and frequently become quite incomprehensible, while they are always open to the risk of unreliability, containing discursive matter of little importance, while vital points are missed. Half the difficulty of report-writing is avoided if a proper diary and letter-books have been kept, as from these there should be little trouble in filling up well-devised report forms independently and accurately, and if the reports be demanded at sufficiently frequent intervals to keep the Clerk of Works up to his work of diary-entering, the risk of anything material being missed by inadvertence is reduced to very small proportions.

While many Clerks of Works have not the necessary literary ability to compose full reports, most of them can ask a definite question or can reply to one concisely and to the point. It is, consequently, the custom in some offices to supply the Clerk of Works with foolscap paper, ruled as follows:—

No. QUERY FROM CLERK OF WORKS.

Building............................

Date............

Question.	Answer.
....	....
....	....
....	....

If a good number of these are printed, and if some of them be upon blue paper as queries from the Clerk of Works, and some upon white paper as queries from the Architect, correspondence is greatly facilitated, the only essential part being that copies should be kept by both parties, so that both Architect and Clerk of Works may be able to refer to the whole correspondence at any time.

CHAPTER II

SETTING-OUT

Some of the most important of a Clerk of Works' duties are those which have to be undertaken at the earliest stage of the contract, for it is then that the building is set out on the ground. He has not to do the setting-out himself, but it is essential that he should check it in every possible way, as once it has been started, and the foundations dug, it is exceedingly difficult to correct any error that has been made. It is possible, for instance, for a Contractor to misplace his buildings altogether on the site, especially on a tolerably open field or amongst underwood which has to be cleared away for it. One of the main points of the building should be fixed by the Contractor or his Foreman, and this should be checked by the Clerk of Works by measuring up to it from other well-marked points shown upon the block plan. At least two such measurements should be taken ; but it is much better to check these two by a third, and in case of difficulty this should always be done. Tape measurements are usually trusted ; but a tape is not a reliable instrument unless it be new, stretching considerably in course of time. A new tape should consequently be used (or preferably a steel tape, though it breaks easily), and at this early stage it is well to mark against a wall—or some other object which is not likely to be destroyed by the works — the exact tape length of 66 feet, measuring it first with the tape and then checking it with great care by means of the 5-feet rod, making marks along the wall at every 5 feet or 10 feet. If at any subsequent time there be any doubt as to the correctness of the tape, it can then always be checked against this standard marking ; and, in fact, this ought to be done occasionally, for the reason above stated—that a tape rarely retains its true length for very long.

When one point of the building has been fixed in this way a second point must be similarly fixed, preferably at the other end of a long wall, of which the first point was one of the corners. It is not sufficient to trust to fixing the first point alone correctly, for if this is done it is possible to lay out the house with a wrong aspect, turning upon this point as on a swivel.

It occasionally happens that one of the walls is described to face one of the cardinal points, or that, as in the case of a church, the centre line shall run due east and west. It does not do in such a case to trust to the compass, for it must be borne in mind that compass bearings are very far from accurate. At the present time the N. point on the compass is directed about 16 degrees west of true north, and this varies slightly day by day, while there is a gradual tendency, though it is a very small one, towards greater correctness. Even were the compass an accurate guide, the small instrument carried on a watch-chain would be utterly unreliable, and even that upon an ordinary level, though it will come to rest (which the little hand instrument will not do), is still liable to be affected by all sorts of accidental causes, such as the presence of an iron spade in the hand of a labourer who is standing near. It is in the writer's experience that an iron railing about 5 feet from his instrument once drew it out of truth to the extent of over 12 degrees.

For most purposes the shadow cast by the sun at noontide may be considered to give a north and south line with sufficient accuracy. In order to obtain this all that is necessary is to erect a vertical pole on a sunny day. Note, and drive a small stake or pin into the ground at the end of the shadow which it casts about half an hour before noon ; then, taking a piece of string and tying it to the pole, stretch it, and holding a sharp stick or some other pointer where the pin has been driven in, describing a circle with the pole as centre, marking it on the ground. It will be noticed that, as noon approaches, the shadow will recede within this circle, and then will gradually come out to it again. When the circle is reached a second time a second pin is driven in, and midway between these two pins will be a point which lies due north from the pole. It must be noticed that the first pin should be driven in a good half-hour before noon, as, although the shortest shadow is always cast when the sun is due south, this only happens at noon twice in each year, being sometimes before and sometimes after that time. Of course, this can be done much more accurately by means of a theodolite ; but such extreme exactitude is very rarely needed in building works. The North Star can also be taken as an index ; but this varies at different times of the year, though its extreme error is only something like 2 degrees from exactitude.

There are cases in ecclesiastical work when it is desired to set out the centre line to the point of the sunrise on some particular Saint's day ; but in such a case the Clerk of Works does best to consult with the Architect, and leave the responsibility of checking in his hands. He may then very likely demand that a true meridian line be given him—say by means of the sun's shadow, as has been just described ;—and from this he

will give instructions as to the angle of declination, which will have to be laid out by the help of a theodolite or some other angular instrument.

If one has not already been supplied, in all probability the Builder or his Foreman will make a foundation plan, showing the outline of the trenches which are to contain the concrete; and it is from this plan that the setting-out would be proceeded with. If this be done a good deal of trouble might be saved by the Clerk of Works going carefully over it, checking each point to see that the proper widths have been provided everywhere. This can easily be done if either it or the ground-floor plan be upon tracing-paper. It is now usually the practice to supply both Contractor and Clerk of Works with a set of sun-prints of the contract drawings; and it is these with which the foundation plan has to be compared. If they are inaccurate, so in all probability will be the foundation plan; and as sun-prints are no more reliable than tracing-cloth in the matter of scale, it is well that they themselves even should be checked against the figured dimensions, and in case of any discrepancy the figured dimensions must always be taken in preference. It may consequently become necessary to draw out a fresh brickwork plan from the ground-floor plan, and to make, or to instruct the Contractor to make, a new foundation plan from this. There should be no necessity to consult the Architect so long as the drawings are sufficiently dimensioned, but in case of real doubt he should be communicated with at once, for, as already said, a mistake at this early stage of the work is a very serious matter indeed.

As a general rule, a Contractor sets out his angles by means of a large square made in his workshops, by setting two pieces of timber at right angles to one another, and binding them across the angle. The accuracy of this is easily tested. It should be laid down, say, on a flat piece of ground, and a line marked along each edge. One of these lines should be continued by means of a straight-edge, and the square should be turned over so that one of its sides rests on this continued portion. The other side should still lie alongside the line at right angles to it, as before. The Foreman's attention should be called to any incorrectness, but, as in everything else, it is not the Clerk of Works' duty to put it right himself. Any angles other than right angles should all be checked by cross measurements.

In the matter of the heights, which involves that of the depths of foundations, a Clerk of Works' responsibility is great. It is always possible upon sloping ground for a Contractor to make a slight mistake greatly to his advantage in the matter of digging. The first thing for the Clerk of Works to determine is what spot upon the drawing represents the present ground level, both in plan and section. This he should take as a datum, and as the level on any given point near the building will be altered again and again he should set up from it another datum at some point which is not likely to be changed, and preferably at two or three such points. Say, for instance, that the ground in front of the principal entrance is to be taken as datum. This point is located on the site, and the level staff is held there, a back-sight reading being taken on to it, say, of 4.23. The level is then directed towards a fence, and the staff is held so as to rest upon the bottom rail of the fence, the exact point being marked first in pencil, and subsequently with paint and a saw-cut, so that it may not be obliterated. Say that the reading here is 2.12. Assume that the first point is 10 feet above datum, this being convenient if none of the excavations are to be carried deeper than 10 feet. The collimation line of the instrument will then be 14.23 above datum, and the level of the bench-mark determined upon the fence will be $14.23 - 2.12 = 12.11$ above datum. This is recorded in the level book, and may very well be painted on the fence. If practicable, and it generally is practicable, the level should be turned round to some other object on quite a different part of the site and clear of the building operations, such as a tree or a gate-post which is not going to be removed, and the staff should be held against it, and moved up and down by the holder, until it again reads 2.12, when a pencil mark should be made at its foot, and this again should be subsequently made permanent by saw-cut and paint, or by paint only in the case of a growing tree, which might be injured by cutting. Thus a second bench-mark is set up, at the same height above datum as the first, so that if either be accidentally destroyed the other can be worked from; while, further, similar bench-marks can in future be determined from them if necessary. It is now known that the point on the ground line, shown on section in front of the main entrance, is 10 feet above datum, and from this it is easy to calculate what should be the height of the bottom of the trenches and of the top of the concrete, as determined off datum, whether the building be a simple one or a complex one, whether the foundations be all carried down to the same level, or whether there be many different levels, with cellars of varying depths; while the drain trenches, with their gradual fall, can be equally well determined. Then, when the trenches are excavated, it is not at all a difficult matter to anyone who is accustomed to levelling to check whether the correct depths have been reached. Say that a Clerk of Works is asked to pass the depth of a certain trench. He consults his section and finds that the bottom should be 3 feet 6 inches,—that is, 3.5 feet below the gravel path before the front entrance. In other words, it should be $10 \text{ feet} - 3.5 = 6.5$ feet above datum. He sets up his level in such a position that from it he can see one of his bench-marks in one direction and the trench in another. Sighting on to the bench-mark, upon which the staff is again held, he this time obtains a reading of 2.27, and this added to 12.11, the height of the bench-mark above datum, determines his present collimation level to be 14.38. Subtracting 6.5 from this shows him that the staff ought to read

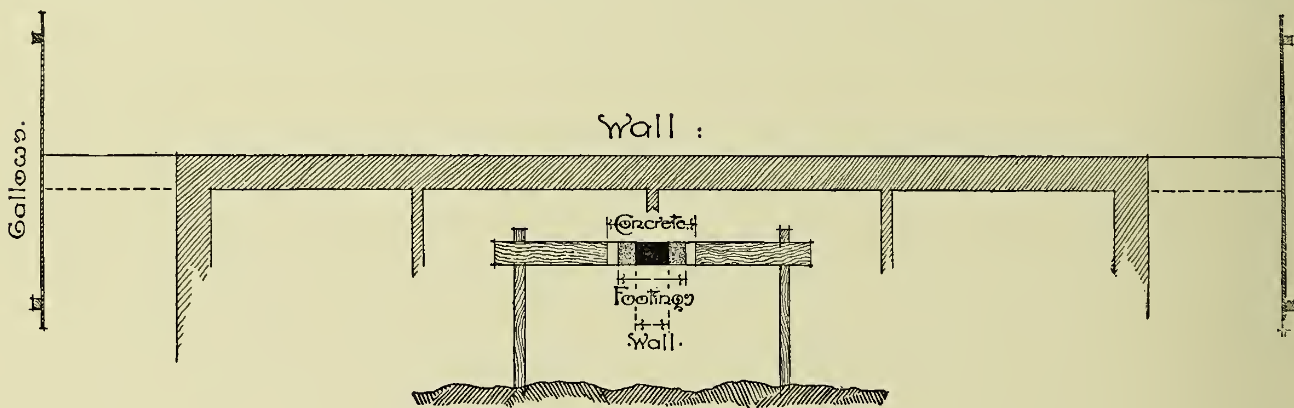
7.88 when it is held in the trench. He instructs the holder of the staff to take it to the trench, and sees him place it there. He finds, perhaps, that it reads 7.90, and with this he is satisfied, as it shows that the excavation has been carried a quarter of an inch too far; and, of course, he would be equally satisfied if the error in the other direction were as slight. In order to test the level of the bottom of the trench as excavated, he now has the staff held in it again at another spot, It should again read 7.90, or very nearly so. If not, the trench has not been properly levelled; but unless there is a material error which would result in the concrete thinning out too much, this may be passed, as absolute accuracy at a trench bottom is not to be expected.

It may be said that it is quite a different matter with drains, which must be kept absolutely true to their proper inclination. The top of the concrete is tested in the same way as is the bottom of the trench; but when drain levels are tested it must be remembered that there is the necessary fall to provide for, and that this should be regular.

Instead of first setting out a front wall or central axis, it is sometimes advisable to lay out a corridor, and, in fact, a line through a building, such as the side wall of a corridor, will often form a better basis for measurements than any other. On a very large building it is well to determine two or three main walls, which run through or across the building, wholly or partially, and if two walls are chosen these are best at right angles to one another.

Having once selected the wall and marked its extreme points, a sight-rail or "gallows" should be put up beyond it at either end, quite clear of the building. This is formed of two stout stakes driven firmly into the ground, one on either side of the centre line of the wall and sufficiently distant from that centre to allow the whole width, not only of the wall itself, but of its concrete foundations, to pass between them. A cross-rail of inch boarding should then be nailed to the stakes, and upon this the thickness of the wall itself, the width of the extremity of the footings, and the outline of the trenches should be marked in the same way that the bench-marks have been, by means of slight saw-cuts and paint. In a wall of great length, intermediate gallows may have to be erected for temporary use, and the saw-cuts marked upon these by sighting between nails driven into those on the extreme gallows. Lines are now stretched tightly from gallows to gallows, attached either to the saw cuts or the nails, and these give the outline of the wall, footings, or trenches, as the case may be. This, as already said, is work which the builder should do, and it is only for the Clerk of Works to check its accuracy, while he should see that the gallows are securely fixed, and are not disturbed until the work has progressed sufficiently for the walls to be independent of them.

A great many Builders trust to small stakes driven into the ground in place of gallows; but these are much more apt to be moved about or kicked over, and are thus liable to cause a good deal of trouble. In all important works gallows should be preferred, and in order that there should be no mistake at all, the length along the cross-rail which denotes the thickness of the wall should be painted, say black, the projection of the footings red, and the farther projection on either side to the outline of the trenches white, as shown in the illustration.



.Elevation of Gallows.

FIG. 177.

Once main walls have been built up to the gallows level and carefully tested they may be taken as a basis for subsequent measurements, and it is generally necessary to redimension the various drawings from these walls, measuring wherever possible from them, and not trusting to minor measurements. This often means a good deal of calculation upon the plans—the introduction of figures upon them in some distinctive colour, as from one side or other of the main base walls. It then becomes of the greatest importance to see that these walls are carried up perfectly regularly, with truly vertical faces and angles. This, of course, applies to all walls, though such extreme care is not always necessary in internal walls as it is in base walls, such as these, and internal walls.

A word of warning may be here given to select as a base wall one which really goes up through the building from basement to roof, for occasionally what looks upon the ground plan to be the best wall for the purpose is not carried up to any great height, or is broken or varied on upper floors, when a good deal of trouble arises through having to select a fresh basis to work from. Verticality can be perfectly easily tested by means of a heavy plumb-line, and truth of direction by the ordinary stretched line, while horizontal coursing is tested by a carpenter's level, the more accurate instrument being very rarely used above the ground floor and for the purpose described last week.

Just as surface dimensions are taken off a base, so are the vertical dimensions, and in this instance the base used would be the ground line shown on the drawings, and considered to be 10 feet above datum. By means of the level and staff, erected for the purpose upon rising ground near or upon a steady piece of the scaffolding, it is quite easy, as soon as the building has proceeded sufficiently far, to determine points upon the walls, in several different places if necessary, all of which are at some known height, say 15 feet, above datum, by the same method as was described for checking the levels of the trenches. These points may be marked in pencil or in some permanent manner upon internal walls which are subsequently to be plastered; but upon external walls the marks, though sufficient for identification, must be of such a character as not to disfigure the work. As the building proceeds other marks can be made, by using the 5-feet rod, at intervals of 5 feet, and from these all heights can be most accurately determined—much more so than is possible by mere measurements from floor to floor. It may be pointed out that it is by no means an uncommon practice for a Contractor to save himself expense by deducting an inch or two from each floor as it goes up, in order, as he may say, that the wall-plates carrying the joists may rest upon brickwork without packing. Everyone recognises that it makes much better work to thus course with the bricks; but a Clerk of Works should be careful to see that if an inch is lost on one floor it is made up on another, if he permits any variation at all. About this, however, he ought to consult the Architect, as a very little difference might upset a scheme of internal decoration. This is easily checked if all the dimensions have been scaled and figured on the section *as from the ground line* (which may have to be done by the Clerk of Works), and if standard marks on all the principal walls have been made at every 5 feet above this ground-line.

The gallows system of setting out walls is also applicable to drains, only in dealing with them the cross-rail should be so fixed, by careful usage of the level and staff, that its upper edge is, for instance, at a fixed height, say 8 feet above the invert of the pipe. A long rod is then cut exactly 8 feet in length, and a cross-piece nailed to its head and another short piece to its foot. Every pipe that is laid can then be tested by erecting the rod, known as the boning-rod, so that the little piece at the foot rests in the pipe, while the cross-bar is steadied between the sight-rails until it exactly comes in line. The position which the pipe is to occupy may be painted on the sight-rail, just as the thicknesses of the walls have been painted on the gallows-rail, and by dropping plumb-lines from these markings it can easily be seen whether the pipes occupy the positions which they ought to do.

CHAPTER III

TESTING MATERIALS

A GREAT part of a Clerk of Works' time is necessarily taken up, particularly during the earlier stages of a building contract, in testing the materials brought on to the site, so as to enable him to exercise sound judgment in their acceptance or rejection. As already stated, diary entries are made upon all these matters, while special entries in a test-book are kept with regard to such materials as cement, the testing of which occupies some time, and is of an elaborate character.

This is one of the most important materials to which tests have to be applied, and with regard to it, as with all others, the Clerk of Works must remember that he is only justified in applying such tests as are mentioned in the specification, or such as will enable him to give a true opinion as to whether the material reaches such a standard as the specification contemplates. If a tensile test is specified, that tensile test should be applied; while if the cement is "to be sound and properly cooled," the tests for these are implied, even although they are not specifically mentioned.

Cement is a difficult material to test, and its proper testing requires apparatus which is not in everybody's possession; consequently, if the more severe tests of tension, boiling, and specific gravity are required, say, in accordance with the specification of the Engineering Standards Committee, and upon small works, it is better to select samples and send them up to some recognised testing association than for the Clerk of Works to test himself. This remark applies also to all other materials which require highly scientific tests to be applied to them. It is most unwise for a Clerk of Works to undertake such if he has had no really scientific training and experience in conducting delicate tests. They lie beyond his province, and he should not hesitate to state this if the question is raised, undertaking only such tests as are comparatively easy to perform on the spot. There is no difficulty, for instance, in applying the test for fineness. What is needed is a measuring-glass divided into one hundred parts, and a small sieve properly graded to the correct number of divisions per square inch, and with wire of standard thickness, such as can be obtained from most mathematical instrument makers. The cement is poured lightly into the glass, filling it up to the point marked 100, and is then thrown on to the sieve and shaken by hand until all passes through that can be got to do so. The remainder is poured back into the measuring-glass; the height to which it rises denotes the percentage of residue. It is perhaps more accurate to weigh the cement before it is sifted, and after, with extremely delicate scales, working out a simple proportion sum afterwards to ascertain the percentage left behind. But this is a little more delicate and difficult, if it be more accurate, and the measured percentage is very generally accepted in place of it.

To test the weight of cement is also quite easy it under the specification it is permissible; but it must always be remembered that it is highly unreliable. A bushel measure must be obtained, and it must be seen that this is stamped by the inspector of weights and measures, it being insufficient to allow such a measure to be made up by the Contractor's workmen, with the possibility that it may be considerably too large. This is filled lightly through a hopper with the cement until it is overfull or heaped, and the surplus is struck off with a straight-edge. The remainder is weighed on an ordinary weighing-machine, together with the measure. The measure is weighed separately, and this weight deducted from the total, giving the net weight of the cement, which is compared with that permitted under the specification. It is usually stipulated that cement shall weigh at least 110 lbs. per striked bushel, but, as said already, this is an unreliable and old-fashioned test, which is generally superseded by that of specific gravity; which, as it needs special appliances and is difficult to accomplish, should not be attempted by a Clerk of Works

It is also frequently specified that the cement shall be properly cooled. This is usually interpreted to mean that it shall not sting the bare hand when plunged into it, a rough test quite easy to apply. It is also well recognised that if the cement strikes cold to the touch it has probably been overcooled, and has become inert. If anything more than this rough test of coolness is required it is best to refer this also to a specialist, though the application of the test is by no means so difficult as is that for specific gravity. A small pat of cement should be made up with 10 per cent. of its weight of water, and a delicate thermometer bulb plunged into it, say that of a clinical thermometer. The temperature reached shortly after the bulb is plunged in should be noted, as also should the rise of temperature during setting, which should not exceed 6°; while inert cement will show a rise of less than 2°.

If the rise be excessive it shows that the cement needs spreading out on a boarded floor under cover, and turning over with a spade from time to time, until such time as a pat treated in this way shows a rise of temperature which is not greater than 6°. Until then the cement is unfit for use, containing an excess of unslaked lime. Of course, if the cement be inert it is valueless, and must be rejected.

The tensile test usually specified is that a cement briquette, after lying one day in air and seven days in water, should not break under a tensile stress of less than 400 lbs. per square inch. This test is sometimes applied by a Clerk of Works on large works if he is provided with a proper testing machine; otherwise he ought not to attempt it. The cement is as usual mixed with 10 per cent. of its weight of water, and lightly trowelled into a mould having much the shape of an hour-glass, 1 inch by inch section at the smallest point. It is left in the mould, lying on a piece of glass or slate, for 24 hours in order to set, and is then taken out of the mould and put in water, kept as nearly as possible at a temperature of 60° for seven days. It is then removed to the testing machine, and a gradually increasing load applied until it snaps, the load that causes fracture being noted. There are several different makes of testing machines; but in all the same result is achieved.

The principal test for soundness is that of boiling, and it may be carried out with quite elementary appliances. A circular pat of cement is made upon glass, slate, or some other smooth substance, about 3 inches diameter, and $\frac{1}{2}$ inch thick in middle, tapering out to the edges. If made in the evening this could be ready by morning for further treatment, care being taken to keep the temperature of the place in which it is deposited well above freezing-point, and preferably as near as possible to 60°. It is convenient to make such a pat upon what is known as a lantern-slide cover-glass, this being $3\frac{1}{4}$ by $3\frac{1}{4}$ inches In the morning, by which time the pat has set, it should be put into a small saucepan or kettle just as it is, glass and all, covered with water, and brought to the boil over a fire or oil stove; and it should be kept boiling for about six hours, fresh water being added as that in which it is immersed evaporates. An unsound cement will not stand this test at all, but will turn to soup in the boiling process, while a good cement will remain adherent to the glass and perfectly sound in all respects. An overcool cement will probably shrink, curling up at the edges and becoming detached from the glass, while a slightly hot cement may show hair cracks on the pat without absolutely disintegrating. For most purposes any cement may be accepted which comes out of the test as a homogeneous pat, though judgment must, of course, be exercised. The effect of the boiling is to accelerate the changes which take place in use, and of these expansion is that which is most to be dreaded. It is undue expansion which breaks up an unsound pat. During boiling this has taken place in the course of a very few hours, but under ordinary circumstances in work the same thing might not occur for several months, and then result in some considerable misfortune, such as the blowing off of the collars of a series of drain-pipes.

This test, like the others mentioned, can be more scientifically applied if desired, by means of an apparatus somewhat resembling an incubator, but, generally speaking, the rough test described above will suffice.

Sand is not a difficult material to test; it is usually specified to be sharp pit or river sand, free from loam. This implies that there should be no softness or smoothness in its feel when rubbed between the hands, and that, if a small quantity be stirred in a tumblerful of water, the water should remain clear and unclouded; but builders are particularly fond of using a loamy sand if they can get it passed, as it is generally cheaper and easier to work up. River sand is sometimes rounded in its grit, but in spite of this may generally be passed. Pit sand, on the other hand, may be loamy, and may even be salt; this can be detected by tasting a little in the mouth. If only loamy sand be obtainable in any given district, and it is specified as above, it is necessary to have it washed, and it is the Clerk of Works' duty to see that this is done thoroughly by placing it in a shallow trough with water passing over it in a continuous stream, while it is turned over occasionally. A few hours' washing will generally remove all trace of loam and even of salt, and render the sand suitable for use. Even sea-sand may be utilised with safety if well treated in this way; but, of course, watchfulness is necessary to ensure that the washing is sufficient. The objection to the presence of salt is that it attracts moisture, and so is likely to produce a damp building.

Gravel and other aggregates for concrete are, in respect of loam and salt, similar to sand. Everything in connection with these, however, depends upon the particular specification. Sometimes a gravel or ballast is specified which is expected to contain a certain proportion of small stuff or sand, while in other cases it is intended that it should be screened, and only the coarser particles used, the sand being afterwards added in definite proportion, with the result that occasionally the sand which is sifted out from the aggregate is again returned to it to make the proportions right. If sifting is specified, however, it ought, as a matter of course, to be enforced.

Lime is not often tested, but judged by inspection; but if there is any suspicion that a pure lime is being supplied when a moderately hydraulic lime is intended, detection is easy on the application of water, as a pure lime slakes much more rapidly than does the other. Possibly the greatest trouble is experienced with lias lime. If the maker be not definitely stated it is possible, and legally permissible, for something else

than a lime from the lias formation to be supplied; but the Clerk of Works should insist, so far as he is able, upon having the real article from one of the well-known Somersetshire or Warwickshire burners.

The presence of impurities, such as sand or colouring matter, if not detected by inspection or by the sense of touch, may be ascertained readily by placing a small quantity of the lime in a saucer and covering it with hydrochloric acid. Effervescence will result, and when this subsides it will be found that the lime has been "digested," any residue left in the saucer being of some foreign substance.

This is also the test to apply to mixed mortar, if there be any doubt as to its proportions. It must be allowed to dry before the test is applied, and weighed before and after the test, the proportion by weight of the residue showing the proportion of sand that has been used.

Stones are generally specified as being free from sandholes, vents, and all other defects. It is rarely that any test is stated in a specification; but if so it is usually one for absorption, either by percentage or by weight of water taken up in a given time by a submerged piece of stone of a given size. This is an easy test to apply, proportion being generally ascertained by weight, needing that the stone shall be weighed before and after the test, and the excess of weight due to the presence of water over that of the dry stone indicating the amount which has been taken up. If the test specified be one of bulk it is necessary to cover the stone with a definite measured amount of water, and afterwards to measure that which is left, the difference, of course, representing the amount absorbed. The only essential precaution to take is that the test be carried out in a vessel which itself does not absorb moisture. A dry wooden tub, for instance, would not be permissible, while an iron bucket might be trusted.

Examination for flaws in the stone is, whether specified or not, essential in all cases, and a considerable amount of judgment has to be exercised in accordance with the particular stone which may happen to be specified, and the position in which it is to be used. If an obviously soft and friable stone be supplied for a position where it is likely to be subjected to wear, the attention of the Architect should be called to the matter, even if it complies with the specification as regards the quarry from which it is obtained, and similarly a stone which is chalky or earthy and soft should be regarded with suspicion for external work. Definite sand-holes can generally be seen by inspection, while vent or cracks are to be discovered by tapping the blocks all over carefully with a pebble. So long as a ringing sound is emitted the stone may be accepted; but directly the "voice" of the stone—if it may be so called — becomes dull, it should be examined for a crack, and the faulty part cut out, or else the block be discarded.

It is not often necessary for the Clerk of Works to determine whether any of the stone contains lime. If it be obtained direct from the quarry there is rarely any doubt as to where it comes from; but sometimes this doubt exists if it be obtained through a merchant. Thus "best York stone," which all know to be a practically pure sandstone, would be rejected at once if, on application of a little acid, it were found to effervesce, showing that lime was present. Such terms as "York stone," for instance, have a very wide signification. Some of the sandstone obtained from Yorkshire is of a coarse grit and deep in the bed, while other is of fine grain and comes out in thin slabs; while all colours, from white through cream to brown, and also blue stones, fully answer this description. It even happens occasionally that York stone is supplied which has been quarried in the Forest of Dean; but this is so hard to distinguish from some of the best York stones that it may generally be accepted.

A most difficult thing to detect about some stones is whether they are being laid on their natural bed, as is specified to be done in most cases. The bed is easy enough to discover in most of the laminated stones, such as the sandstone landings, while in other cases it is immaterial, as in the thickly bedded and homogeneous stones. In shelly stones it can be discovered by the direction in which the fossils lie, as naturally they will have been deposited flat on the sea-bed originally. Thus a fossiliferous stone must always have its shells lying down on its side when it is flat bedded. In the oölites the discovery of the bed is difficult, unless there be fossils present, except by a skilled workman, who will know it by the feel of his tool as he works the surface.

A slate which does not ring properly when struck is sure to be faulty, being probably of an earthy character and highly absorbent. Absorption is tested by standing a slate upright, partially submerged in water, when it ought to show no sign of moisture creeping up the edges within half an hour. Some slates will, however, become moist in that time as far as 2 inches above the water-line, and, of course, any such should be rejected, for there should be practically no rise of moisture at all. A bad slate, too, will give out an earthy odour when wetted. Many Architects prefer a slate which splits very thin; but such are by no means the best for roofing purposes, as they are exceedingly liable to crack, and a strong and comparatively thick slate of rough surface is often to be preferred.

Of all the materials supplied upon a building, timber is that upon which the exercise of judgment upon the Clerk of Works' part is most essential. Under the usual specification there is a great deal left to the imagination; or perhaps it would be more proper to say that that which is specified is generally difficult, if not impossible, to obtain. Architects go on specifying Memel, Dantzic, or Riga timber, in spite of political events upon the Baltic, and the facts that the Prussian and Russian forests are nearly worked out, and that a

great deal of so-called Baltic timber is imported from Canada and the United States. This is so nearly allied to that which it was the Architect's intention to demand that it may generally be accepted; while in very many cases it would be impossible to distinguish the one from the other except for the brands. Thus good sound fir may generally be passed for carpenter's work wherever it may happen to come from, provided that it be clean, straight, and not too open in grain, fairly free from knots, and well seasoned—all of which can be seen by inspection. The proportion of sapwood which may be allowed is often a difficult point, upon which it is well to consult the Architect at an early stage. If in the specification it says that the timber shall be absolutely free from sap, there is no question as to its legal meaning; but it may be very difficult to get it, especially in the larger scantlings. Even the smaller scantling stuff, as frequently imported now, is cut from quite young and small trees, and so contains a large proportion of sapwood. Thus if the word "absolutely" be not present in the specification, merely "free from sap" means nothing more than "reasonably free from sap," and the Clerk of Works' position becomes difficult, as the onus of judgment is thrown upon his shoulders.

Any tendency to decay, other than the presence of sapwood or of actual rot, can be detected by tapping the timber and noting the sound given forth, which ought in no case to be dull; while a slight tap with a key at one end of a piece of timber should be distinctly heard if the ear be placed close to the other end. A speckly or dotty appearance is also indicative of incipient decay. Even although the specification may make no mention of it, waney timber, especially if it run out to the bark, may always be rejected, as it necessarily consists almost entirely of sapwood; and so, of course, must warped timber, or that with broken grain, or containing large loose knots.

Joinery work ought always to be inspected in the shops before it has been put together, to make sure that no unseasoned rubbish or sapwood has been used. If it is not seen until it has been brought upon the site there is much greater hardship in rejecting it. Some Builders will do their very best to get the Clerk of Works to accept joinery which is sent on to the work ready primed. The woodwork thus being covered by a thin coat of paint, it cannot be seen whether it contains defects or not, and in no case should this be permitted.

With regard to metalwork, it is a very common practice for Architects to specify tests which they never mean to have applied, such as those for the ultimate breaking weight of the metal. If it be obtained from a good firm, as a general rule the firm must be trusted, as only in large works is it possible to cut test pieces and have them subjected to direct tensile tests. In ordinary building work all that the Clerk of Works has to do with regard to metal is to see that what is supplied is sound. Large castings, for instance, should be carefully tapped all over with a light hammer, in order to detect flaws by means of sound; and it should, of course, be seen that all bolt-holes have been cleanly drilled, and that bearing surfaces are true. Steelwork, in the same way, should be carefully tapped all over, particularly the rivets, in order to discover any that may be loose, which would have to be cut out and replaced by others. The rivet-heads should also be in proper alignment, and whether it be specified that the bearings are to be planed or not, these should all be sufficiently perfect for no wedging to be required. Under a bad specification this may be exceedingly difficult to insist upon; but with the exercise of firmness and tact good work can generally be obtained, even under such conditions. In large works where much steel is used, testing ought to take place with stringency; but it should be done by keeping a representative at the mills, who could have test pieces cut from the various plates and girders before they are built up, and tested at once, rather than on the works.

There are few other materials about which definite directions for testing need be given, as all Clerks of Works of any experience are able, for instance, to discriminate between good sheet glass and that which is wavy, and to detect whether lead of the full weight specified has been supplied. In these days of ready-mixed paints it is not often that adulteration is attempted. It is always best to have paints which have been mixed by proper machinery than those which have been made up by hand; but if the latter be specified or permitted, then it is just as well to test the white-lead by placing a little in a saucer and covering it with nitric acid, which will dissolve the lead and leave any adulterant as a residue.

CHAPTER IV

SUPERVISION

If ever there is a time when the Clerk of Works has to be more constantly upon the site than at any other, it is during the digging and laying of the foundations. These are generally shown upon the plans as of certain widths and depths, while the specification gives power to the Clerk of Works to order any further digging that may be necessary. Whether this power be definitely given him or not, however, he is obliged to exercise it if occasion demand, for in foundation work emergencies arise at very short notice, and must be dealt with at once, always bearing in mind that anything of a serious nature should be immediately communicated to the Architect.

If trial holes have been made in advance, and the trenches be found to conform to what was anticipated, there is rarely much difficulty; but, for all that, watchfulness is essential. It has been known, for instance, for new work on an open field, where it had been ascertained that there was a good subsoil of gravel demanding no extra precaution, to be suddenly interrupted by the excavators opening up an old Roman brick kiln, occurring just under the corner of the contemplated building. Frequently, too, streams of water are met with just as unexpectedly, and these, unless they are attended to at once, will often swamp the whole foundations and do a large amount of damage. Even the smallest trickle of moving water must always be viewed with suspicion, and carefully provided against by drainage into a larger stream if possible, in addition to temporary pumping to keep the water down while the foundations are laid. It must always be remembered that, however small a stream may be, it will eventually sap a foundation if it be continuous, and possibly the result will be settlement and destruction. Soft pockets, too, in an otherwise firm subsoil will frequently occur, and must in all cases be dug right out, and filled in either with concrete or hard core—preferably the former—while in serious cases piling may have to be resorted to. If these pockets occur on the sides, and not at the bottom of deep trenches, it often suffices to support the weak places by strutting and planking till the permanent work is completed; but this must be done promptly, else greater expense will be incurred in entire removal of the loose stuff, and its replacement by carefully rammed core or concrete.

When building upon old sites there are many other difficulties to be contended against. One may be on virgin soil one moment, and the next moment find that one is cutting across an old trench which has been filled in with rubbish. It may not be necessary to carry the foundation down to the bottom of this trench, but all the same it ought to be dug right out, so as to ascertain to what it leads. Soft earth such as is often found packed in in this way may occasionally be bridged by putting a good concrete block on either side and connecting these two blocks with steel joists round which concrete is packed, and this may eventually have to be done; but the wise course is to dig the trench out in any event, as there may be an old pipe or drain at the bottom which, with its open joints, is depriving the soil above of its necessary moisture. It is also by no means uncommon to come across old cesspools in this way, and, needless to say, they must be dug right out and their contents mixed with chloride of lime, or quicklime immediately, before being carted away, and the excavation similarly treated before it is filled in. Sometimes, where a trench has been filled in by the soil taken from it, there is considerable difficulty in discriminating by inspection between the original soil and the filling, though otherwise a distinct line can be seen between one and the other; but where this difficulty occurs the man with the spade can generally distinguish the one from the other by the ease with which he can cut into the filled-in work.

How to deal with all the cases that may arise it is impossible to explain in writing, as it is rare that two are alike. Only experience can lead to a sound decision in any case; but it is better to err upon the side of too great precaution than too little, keeping in mind the main points,—that moving water must always be given free means of escape, that soft places must be bridged or filled in, and that sandy banks must be held up so as not to fall into the trenches. Where a definite change of strata takes place, whether by what is known as a "fault" or by the ordinary running out on the side of a hill, it is well to consult the Architect, as it is just at such a point where a building may fail through unequal settlement; but the method of dealing with such a case is hardly a matter for a Clerk of Works to decide.

Concrete, whether intended for foundation work or for floors, needs careful watching, both while it is being mixed and while it is laid. So much depends upon accuracy of proportion that the Clerk of Works should see that proper measures are provided, and insist on their being used. It is also essential that the mixing

should be done on a clean surface, preferably of boards, and that the materials should be turned over when in a dry state sufficiently to incorporate them thoroughly, then watered through the rose of a watering-can, and on no account douched with water from a bucket or hosepipe, and afterwards just turned over lightly again and gently shovelled into place. There are many mechanical concrete mixers on the market; but they are only economical when the concrete is to be used in great bulk, and are rarely employed upon building operations. Unless very carefully watched the workmen are likely to be slovenly in the mixing, and to tip the concrete instead of shovelling it. There is also a tendency on the part of many careless men to leave big lumps of stone amongst the aggregate without properly breaking it up, so that the screening to size specified should be watched.

When concrete is used for walls much attention must be paid to properly wetting each layer before the next is laid on top of it, so that there may be thorough adherence. When the walls are of what is known as armoured concrete—that is, consisting of concrete in which steel rods are embedded—it is of the very utmost importance that the steel and concrete should be intimately connected. It is consequently necessary that the aggregate should be very finely broken, and that the concrete should be lightly rammed, so as to expel all air-bubbles and make it perfectly homogeneous, bringing it into tight adherence to the steel.

This also applies to floors and staircases, and, in fact, to all concrete which is worked into moulds or packed round any supporting material. Concrete floors must in all cases be protected against rain, direct sunshine, and frost, and of course against traffic over them, until they are set, by means of sacking or boarding. Usually seven days' protection is sufficient; but judgment must be exercised, and the covering kept on till the surface is really hard. In the same way, no centering for concrete floors or boarding for concrete walls should be removed till quite a week has elapsed.

Frost is the greatest enemy of all work into which water enters. Consequently brickwork and masonry which is laid in mortar must be built in quick-setting cement, if it is done in frosty weather, or else must be thoroughly covered over at night-time during the winter months, and whenever the temperature falls below freezing-point. Pointing is particularly liable to be attacked, as it lies on the surface of the work, and should never be done, except in cement, at a time of the year when it is likely to be destroyed in this way. Even cement, however, whether in concrete or mortar, must not be allowed to freeze before it is set, else the setting action will be entirely stopped, and the work will break up as soon as the thaw comes, as readily as if nothing stronger than sand had been used.

In masons' work, once the Clerk of Works is assured that the stone is sound, he generally has little trouble; but he ought not to permit hollow bedding unless the Architect particularly asks for it, as, although it results in the production of a fine joint, it renders the stone liable to spall off. He must, of course, see that all joints are properly flushed up with mortar of the character specified, and that backing is properly filled in. Walls which consist of ashlar facing and rubble backing ought to be built very slowly on account of the unequal settlement, and should be provided with good bond stones as frequently as circumstances will permit; and the same remark equally applies to ashlar walls which have a brick backing. It is always best in such cases for the backing to be laid in an eminently hydraulic lime, if not in cement.

The bedding of the stone has been referred to previously. Horizontal bedding is especially necessary in landings and stairs, and is generally insisted upon throughout all mason's work, except in overhanging mouldings, which ought to be edge-bedded, and tracery, which ought to be bedded at right angles to the pressure exerted on the stone.

In all walling, whether it be built in brick, stone, or concrete, the verticality of the face must be preserved and watched, testing it with a plumb-line constantly. In the same way the perpends, or vertical joints, which ought to come above one another, should be tested; while the horizontal courses are tested by means of the ordinary level, or in long lines, perhaps by the use of the Surveyor's level, though this is rarely done. A careful Clerk of Works will always see that stone steps immediately after being laid are covered with boarding to protect them from injury until the completion of the work, and in the same way all projecting moulding and carving has to be covered after execution. A good deal of carving is generally left until the very last, and is worked *in situ*, so as not to need further protection after the scaffolding in front of it is removed.

Brickwork is similar to stonework in the matters mentioned above, but requires a good deal more attention to secure proper bonding. All bricklayers know how to form simple angles and junctions; but anything that is in the slightest degree out of the common should be specially set out by the Foreman, and submitted to the Clerk of Works for approval before it is executed, his duty being to see that there are as few vertical straight joints throughout the work as possible. This is particularly necessary in flues and chimneys, and in brick piers which are introduced for supporting heavy girders. Footings also need watching. Headers should be used in these to the greatest possible extent, unless each course be a double course, when the lower may consist of stretchers and the upper one be of headers. The proper cutting of arches, whether of brick or stone, needs careful watching; as also does the laying out of the flues, which ought to be parged as they are built, and carefully smoothed out with a trowel, it being now a very rare thing to core them in the old fashion—that is,

to build them round a core, or open box of wood with rounded angles, which is drawn up through the parging almost course by course as the work proceeds. Coring is always specified; but it now means little more than passing the sweep's broom through the finished chimney. The most likely things for the bricklayer to slip are the little finishings, such as cement fillets and cement pointing, whether to window frames or to lead flashings, and proper cement weatherings on the top of all over-sailing courses, and as flaunchings to chimney-pots. A good deal of trouble may be caused also by the surfaces of internal walls being improperly finished; being, for instance, left rough when it is intended that they should be whitewashed, or finished off with a neat joint when they are to be plastered. If it is specified that the external facings are to be struck as the work proceeds it is necessary to see that this is done, and that the walls are protected from injury subsequently. It is always much easier to the Builder to leave the joints rough for subsequent pointing and smoothing down, rather than to keep it clean from the outset. It is essential to watch that no stale mortar be used. There is almost always some over at the end of a day's work, and this the men are tempted for their own sakes to work it up next morning, while it is an economy for the Builder to permit them to do so. It requires a Clerk of Works to be at his post as soon as the men arrive if this is to be prevented, should he suspect it being done. Mortar which has once set, whether it be made of lime or of cement, has very little adhesive power afterwards, and cannot be trusted. Cement particularly has to be mixed in quite small amounts, and used quite fresh, as much of that which is now on the market will commence to set within half an hour of the mixing. To a less extent this is the case with the more hydraulic limes, and consequently if they are being used the watermill should be employed with care, else it may continue its work after setting has commenced, and thus greatly destroy the strength of the mortar.

It is almost invariably specified that no one part of a building shall be carried to a greater height than 5 feet above any other part at any one time, except, of course, finished work. This is done to secure equal settlement as the building proceeds, else the portion which is carried up highest may settle before the rest is brought up to it, and a crack eventually appears at the junction. There are occasional circumstances, however, when it is wise to relax this rule, such as, for instance, when an important lintel stone cannot be obtained from the quarry, and the whole work would have to be stopped if no other portion of the building could go on until this stone were obtained. Under such circumstances the walling must be stepped back gradually, so that a vertical straight joint does not occur, and the Architect should be communicated with, as he may prefer to stop the work.

It may happen that stone which is not delivered may be temporarily replaced by courses of brickwork laid in sand. This enables the work to go on, especially if the sand courses are only face deep, without any material damage being done, the stone strings being afterwards introduced and bedded in cement. This is not infrequently done, particularly with shallow stone or moulded brick strings. If window-sills are inserted as the work proceeds, there is considerable risk of unequal settlement, the heavy jambs bearing down, while the space beneath the sill, not being weighed, exerts an upward pressure upon the stone, with the result that the sill will break across. This is entirely obviated by inserting the sills after the whole of the brickwork has settled. In this, as in all cases where stonework or the ends of metal or wood beams are subsequently introduced, it must be seen that the pinning-in is properly done in cement.

Where new work adjoins old it is a common practice to connect the walling by toothings; but these tend to separate as the new work settles down, as it is certain to do, if in ordinary mortar, to a cosiderable extent. Connection by means of a straight joint and a chase is consequently better, allowing of free vertical movement or sliding, the junction being pointed up when the whole has taken its bearing finally.

The points requiring attention in connection with slating and tiling are comparatively few, though they are of no less importance than those connected with the other trades. The principal thing is, very naturally, to see that the roofs are all water-tight, and that the specification is carried out with regard to the method in which the slates or tiles are laid. An endeavour is frequently made upon the part of a certain class of Contractor to substitute an inferior quality of nails for that which is intended to be used, while, of course, no broken slates should be permitted to be introduced. The lap must be kept, and cut slates, such as occur against hips and valleys, must be properly secured. Double courses at eaves are not often missed; but the Slater sometimes needs watching, to ensure that the lower course is laid with what is usually the upper side undermost. In tiling work, tile-and-half-tiles are obtainable, and should always be used against verges.

Any plumber's work in connection with roofs ought to be done, if possible, before the slates are laid. This is difficult in the case of flashings, but is possible if soakers are used, when the two trades can be at work concurrently. Slates are liable to breakage if walked over, and this should be avoided as much as possible, as once a slate is broken it cannot be replaced so as to leave a perfect job without stripping the whole roof. If soakers are used beneath slates, watchfulness must be exercised, else there is risk of the Slaters' nails being driven through the leadwork, and a way thus made for moisture to penetrate. The necessary lathings and battens should be tested for gauge before the actual slating is commenced, and this is best done by counting the number of laths in a certain length of

roof, measured along slope, and making a simple arithmetical calculation as to whether this gives the proper gauge. Just as Slaters' nails must not be driven through lead, so must they be kept from penetrating the under-felt, if there be any, though necessarily the batten nails must do so in order to reach the boarding below, should boarding, felt, and battens all be used. Any nails which penetrate the boarding ought to have their ends clenched, especially if the space within the roof is utilised.

Pan-tiling, if used at all, ought to be bedded in hair mortar, while plain tiles are also sometimes torched on the under side. Valleys are difficult to form in tiles, except to certain pitches of roof in which valley-tiles are obtainable. If lead valleys are specified it is much best to use soakers, if the Architect will permit, or to round off the angle with plain tiles carefully laid, as a large open lead valley looks very bad in a red-tiled roof, while a secret valley is liable to choke with snow. If valley-tiles are used, pointing in cement is necessary. In large roofs tile-hooks are valuable in order to prevent the tiles from being stripped by high winds, while projecting verges need protecting in the same way and for the same reason, either by a cement fillet or by a barge-board.

It is necessary, too, to see that all roofs are laid to their proper pitch, and that these pitches are sufficient, in accordance with the material employed. Slate roofs are rarely permissible at less than 30-degree inclination to the horizon, while tile roofs need a pitch of 45 degrees, except certain patent forms, such as Major's and the Broomhall, which can be employed to as low a pitch as slates.

Metal roofs can all be laid almost flat, a fall of 1 in. in 10 feet being generally considered sufficient, though more should be given if it is obtainable, especially with lead, and if the distance between the drips be more than 8 feet. Sometimes, in long gutters, lead is laid with drips even as much as 15 feet apart; but this is an exceedingly bad practice, as the metal is one which expands in hot weather and forms ridges, while it does not regain its flat shape when the temperature falls again. After a few years of this the lead will crack, and moisture will be admitted. The proper formation of drips and rolls needs extremely careful watching, both in lead and zinc, as there is a great tendency upon the part of both workman and Contractor to allow insufficient lap. This should always be enforced, the lead being carried not merely over the roll, but a few inches along the flat besides, the general specification of first-class work being sufficient justification for enforcing it. It is also necessary to keep an eye upon the thickness of metal which is being used, weighing a square foot if there be any suspicion of a light weight being supplied, it being borne in mind that 7-lb. lead is made both "heavy" and "light." In other words, while apparently of the same thickness, there is a quality of 7-lb. lead on the market which weighs little more than $6\frac{1}{2}$ lbs. per square foot.

All copper work is generally executed by special workmen under a special contract, and so is asphalt, where asphalt flats are used. As a result there is rarely need for such close supervision as when the Contractor's men are employed, though, of course, nothing should be allowed to be scamped. Any asphalt skirtings must be allowed to tail into mortar joints, and be provided with a key; while, if any be brought up against the sides of wooden lanterns, this key has to be provided by driving into the woodwork a number of scupper-headed nails, and by cutting a small chase or groove on the top of the wood skirting. Where asphalt eaves occur they are best formed over a small strip of lead. With proper precautions, asphalt flat roofs may be laid upon boarding with quite as satisfactory results as lead, while it is much more permanent than zinc, and has the advantage over either that no drips are necessary, so that it can be employed when the fall obtainable is exceedingly slight. One inch in 5 feet should, however, be given when possible.

In all internal plumbing and gasfitting work particular attention has to be paid to the jointing of the pipes, none but wiped joints being allowed in lead pipes, and the joints of iron pipes being properly screwed up on red lead. The running of the pipes, too, is a matter very largely under the Clerk of Works' control. It is not for him to lay down where they shall go, but to demand from the Builder that all schemes shall be submitted to him, and he must exercise his judgment upon them, remembering that it is just to the Contractor to permit him to take the shortest routes so long as these are satisfactory; but that he must on no account permit this consideration to override that of placing them in the best positions for efficiency. Water-pipes, for instance, must be kept away from external walls, so as to protect them against the action of frost, even if this involves a somewhat lengthy journey; or else, if carried in an exposed position, must be properly cased in asbestos or felt. There is a frequent tendency, also, to carry pipes through structural portions of the building in such a way as to weaken them, and particularly to introduce them into chases cut into the concrete facings of steelwork. As anything of this sort tends to weaken the building, or to render a fire-resisting coating inoperative, it must, of course, be forbidden. The proper trapping of all sink, bath, and other wastes needs constant observation, particularly to see that all necessary anti-siphonage pipes are introduced in such a position as not to be liable to be choked, and that no pipe is contrived to act as a siphon, and that double-trapping is in all cases avoided. The writer has come across instances in which bath wastes have been double-trapped, and also where a bath at a high level has discharged through a trap into a long pipe

leading down into a yard, with no opening at its head. In both cases it was necessary to nearly fill the bath before any discharge took place, and then it occurred with a rush, accompanied by great noise, the pipes siphoning out; yet in both these instances the work had been done by good Contractors. Hot-water systems, too, may easily become inoperative through some simple neglect of the ordinary laws, and these, as well as gas-pipes, should always be tested before the work is passed — the hot-water apparatus by actually lighting the fire and trying it for a day, and the gas, after the fittings have been fixed, by turning off all the taps, turning on the main cock, and watching the meter to see whether any gas is passing out through leaks, the smallest leakage being traced and stopped. Sometimes this is a difficult matter; but the fault most often occurs in the fittings through an ill-constructed tap, and comparatively rarely at the joints in the pipes, if these be of iron, as they ought to be. Compo gas-piping ought not to be permitted in good work at all, especially if it be hidden under plaster, as it is quite possible for a nail to be driven into it for picture-hanging or some other purpose, and a serious leak to be thus caused. Similarly, all lead pipes should, if possible, be kept outside the building, except that it is customary to make cold-water pipes of lead; but these should be cased and not covered, so as to be always accessible in case of a leak or a burst.

Electric wires, whether for lighting or bells, should also be in casings, and either the skirtings or the picture-rails may be utilised for this purpose, so long as they are accessible and so constructed as to be opened in case of necessity by merely removing a few screws.

The great difficulty with painting is to ensure that the specified number of coats have been applied, as memory cannot always be trusted as to what has been done in any particular part of a large building. It is generally best to keep a tabular list, insisting that each coat should slightly differ in tint until the final colour is reached, the Clerk of Works seeing for himself that his instructions are complied with, making notes, in the form of a list, in advance as to what tints he requires to be used, giving a duplicate of this list to the Foreman, and crossing off both on his list and the duplicate each tint as he sees that it is done, attaching his initials if called upon to do so. If this difficulty occurs with colour, it is even more in evidence with regard to coats of varnish or of oil, as these have no definite tint, and watchfulness is all that can be advised.

PART IV

AUSTRALIAN PLANNING AND CONSTRUCTION

CHAPTER I

INTRODUCTORY

(*Contributed by R. J. Haddon, F.R.V.I.A., F.S.A.I.A.*)

Australian architecture, as we see it to-day, has in its different phases all the variations of development from the primitive slab wood hut to the magnificent granite pile that marks the corner of her most modern city; for, be it remembered, Australia is a vast continent with scattered settlements over distant areas, yet gathering into the great coastal cities some of the finest streets and most substantial and costly buildings in the Empire. And when it is borne in mind that this development of colonisation has extended only over a period of a little more than one hundred years, the question of Australian building, with its problems of planning and construction, must needs present many interesting features to the architect.

Upon reference to the map (Fig. 178) it will be seen that the continent comprises the five States of the Commonwealth, namely—New South Wales, Victoria, South Australia, Queensland, Western Australia, and Tasmania,—with many adjoining islands of minor importance, each State having its own local parliament and capital city. To these capital cities we should direct our attention, for it is characteristic of Australia that by far the greater numbers of the population are found in them, namely—Sydney, Melbourne, Adelaide, Brisbane, Perth, and Hobart.

These cities lie at the following distances from each other:—

Sydney to Melbourne		577 miles
Melbourne to Adelaide . . .		483 ,,
Sydney to Brisbane		733 ,,
Adelaide to Perth .	(about)	1500 ,,
Melbourne to Hobart .	(about)	450 ,,

Now, grasping these simple facts, it will be readily understood that though there may be, and there are, many things in Australian architecture that are common to the whole and typical of the whole continental practice, yet between Tasmania on the extreme south and Brisbane away north, not forgetting the scattered townships far up the Western Australian coast, there is a vast difference in climate and natural conditions that has found reflection in the buildings and works.

Climate and available material will affect building

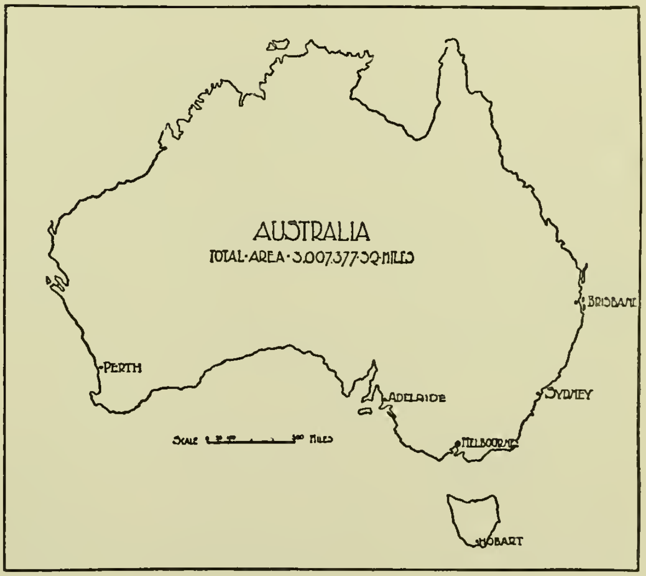


Fig. 178.

wherever found, even in spite of the prejudices of the designer in favour of certain typical forms. The set English form is most noticeable in the early work; in parts of old Sydney and in Hobart there are quaint examples of the terrace cottage built right up to the street line, with cramped back-yards and the quite English way of making one yard common to a row of tenements; and a general treatment of building more

suited to a bleak climate than to the sunshine of Australia.

Public Buildings

The history of the public buildings of Australia is the history of romance; for it runs side by side with the marvellous development of many of her gold cities, and lies close to the pioneering life of many of her most adventurous spirits; for cities have been pegged out in the heart of forests and over the wastes of the desert in a day and built in a decade, and now stand replete in all the modernity of substantial buildings, well paved streets served with all the latest electrical means of locomotion and lighting, and presenting, as such cities as Ballarat in Victoria and Kalgoorlie in Western Australia do, wonderful examples of the energy of the colonists.

The public buildings are always among the very first structures to be erected in a new township; for to the Government the people look for so many conveniences undertaken in the old country by local rather than central authorities. In Australia "The Government" looms large in every place, and the Government buildings stand well out in city and township, and have set a standard for design and substantiality, followed closely by the bank buildings in structural importance.

The enterprise which many of these buildings represent is often surprising when one remembers the tremendous difficulties of the early days of settlement. It is only ten years ago that as much as £150 per ton had to be paid in Western Australia for cartage alone of material for some of the buildings upon the goldfields, when the only means of conveyance was by camel back over desert country; yet at such enormous expenses the Government did not shrink to supply post offices, hospitals, wardens, courts, etc., for the pioneers, and when the cry was for water, hundreds of thousands of pounds were paid for dams, tanks, and condensers ere the great pipe line of pure water was laid over the 500 miles of country from the hills of Mundaring to the sandy plains of Coolgardie.

Suburbia

Though Australia has to be considered, by reason of its area and resources, distinctly a pastoral and mining country, a decided feature of its life is the large proportion of its population dwelling in and near the capital cities, and for the accommodation of this ever increasing demand the suburbs have grown and expanded in all the chief cities, until we find suburban cities joined to the great cities and miles of expansive suburbs holding the land and ever pressing back the rurality of the country beyond.

Each suburb has a tendency to create its own main business street, double lined with attractive shops, feeding the close area of terrace and villa houses, with the mansions of the rich on the outskirts.

The suburbs, being separately governed by local councils, have each their own building laws and regulations, which are reflected upon the buildings erected, a common practice being to separate a brick area from a wooden area and to give supervision through the official building surveyor. These councils have full powers to tax property, to make roads, to create and maintain public gardens and reserves, while the water supply and sewerage, the railway and often the tram services, are owned and controlled by the central Government. Official supervision is therefore given in a general way to suburban building, and regulations have to be complied with in all the closer areas, while beyond these areas, in the shires, the builder is to an almost unlimited extent free to follow the bend of his own fancy and the exigencies of building requirements, though even there the tendency to too great flimsiness of construction is checked by the demands of the powerful association of fire insurance companies, who, owing to strong combination, are able to heavily load doubtful risks.

Even in Australia one speaks quite as a matter of course of the "old suburbs" and the "new suburbs," and certain it is that there is a marked difference between the one and the other.

The old suburbs join on to and are at the doors of the cities, and show for the most part the more distinctly old country type of two storey stuccoed terrace house, generally with the addition of verandah and balcony front, and sometimes — though not generally—with attics above. There are, too, in the old settlements many houses opening directly upon the street frontages. The larger houses were for the most part square and box like in plan, stuccoed and ornamented in the Renaissance manner, lofty and roomy withal, but greatly lacking in æsthetic qualities. Here and there, however, one comes across a nice quaint piece of well designed work that the hand of time has helped with colour and the garden trees with mystery.

The movement towards the new suburbs was slow at first, but set in with great force and strength from the larger cities some fifteen or twenty years ago, when the demand was for distinct land lots and detached residences. From that time on and at the present there is a brisk demand for the modern villa, and it would not be too much to say that scores of thousands of villas have been erected during the past ten years, and at no time was the demand more keen than at the present. This demand has unfortunately been at the expense too often of the older terrace houses that pass more and more into the hands of the boarding-house class, with lowered rents and prestige.

In any description of "Suburbia" we must remember at the very first the delightful situation of Sydney, with the picturesque outlands stretching her suburbs right out to the Pacific Ocean. A charming situation truly, and one of the most greatly gifted harbours in the whole world.

To imagine Sydney we have to think first of a narrow cliff-guarded entrance from the ocean opening into a secure harbour, with hills on every side sloping down into deep water, having a thousand indentations all around, and harbour upon harbour beyond, and rivers running into all, mysterious, changeful, yet expansive, truly unsurpassed as a dwelling place for man and a secure anchorage for his ships; and the greatest ships come right up to the very heart of the city at Circular Quay, the starting-point of all the quickly propelled steamers that convey her thousands to their suburban homes.

And if Sydney be blessed in her situation she is also blessed with good building material, and the whole atmosphere of the place has evidently had an influence upon her architects and her people, for there one sees some of the best work in Australia.

Freestone of the finest quality, and varying in colour in different quarries, but generally known as Hawksbury sandstone, is in abundance, while the Wianamatta shales that overlay the stone deposits provide the principal material for brick making.

The Mansions

The success of the pastoralist, and the position of the governor, the judge, and the rich resident have brought into existence many large houses that may well be classed as mansions. Houses of thirty to fifty rooms are quite common in the suburbs of Sydney, and the "Toorak" of Melbourne is well known; while all the other capitals hold large houses of the wealthy, and the broad lands of the pastoral districts are dotted with the mansions of the squatter.

Ecclesiastical and Educational Buildings

For a country with but limited traditions and without an Established Church, Australia has considerable work to show in church and school building. And if her own traditions be but short, the traditions of her colonists, hieing back as they have done to the old world, have brought with them the spirit and the atmosphere of those memories that have enriched the land of their fathers with ecclesiastical art. Each man has built according to his convictions, and the various denominations have shown a desire to establish in a new land those structural and decorative forms that have been for the centuries clustered around their shrines. Hence there has been great diversity of style, rather more marked perhaps by adherence to old forms than to new conditions, but yet showing signs here and there of some virility and conformity to climate and circumstance.

The practice of the colonial Governments in granting for religious purposes free sites of land in cities and townships gave the first impulse to church building, and many of these sites have since, with the advance of the cities, become of the greatest value, and in some cases sources of large revenue, several of the most conspicuous sites in such cities as Melbourne and Sydney being occupied by church property. Added, then, to private generosity and the establishment of bishoprics and chief churches, there are many large and fine Australian churches to-day, some finished, others with well-laid schemes await their final completion.

Australian Newness

With old world thoughts and experiences thick upon us, Australian architecture comes as a surprising demonstration of the *new*. So used have we been to seek out and admire the old buildings, to gather together precedence for our practice, that we find it at first somewhat difficult to reverse the order in these southern lands, where all is new and the old is only fifty years, and the very, very old only marked by the century. Yet even this in itself makes the object of study interesting, and in its very newness there is the charm of novelty and the hope of the virgin field; for the old soil may answer to the tilling of the husbandmen, but what may not come from the soil before untouched?

Our future hopes for Australian architecture are centred around those now few but hopeful examples of naturalistic treatment of native building material, coupled with restraint and breadth of design, that do so much towards the creation of a truly national style.

When carefully analysed it will be seen how wonderfully the bright sunlight makes for itself effect, even with plain projection of roof eaves and oversailing brickwork and the deep recesses of arch or portico; the broad form is all sufficient without the too common overloading of petty detail and convolution.

The architects of Australia have laid the whole world under tribute for ideas, and many and widely varied in character are the results in the work now before us. Rapid have been the changes from one general tone of design to another, and we cannot help feeling that these changes have, on the whole, been for the betterment of the work. That climate and local conditions will tell more and more upon design we feel sure, and in their telling there may be evolved from the whole, by the passing of the years, that which may be taken as an Australian style, resonant of the soil.

CHAPTER II

DOMESTIC PLANNING

(*Contributed by* R. J. HADDON, F.R.V.I.A., F.S.A.I.A.)

THE average character of the Australian cottage differs somewhat markedly from that of England. The English preference for a two-storey treatment, even with the smallest accommodation, is laid aside before the Australian preference for one-floor treatment.

The three plans given in Fig. 179 are of cottages that have been built upon limited allotments of land, and show the generally differing treatment.

A. Is a timber cottage of the simpler type much seen in the suburbs of cities and large towns with ordinary "cottage fronts." A centre passage leads directly into kitchen, and through scullery to garden. Height of ceilings 11 feet, with internal plastered walls and iron roof. The treatment is one-storey, permitting the passages to be top lighted.

B. Is a seaside cottage, also of wood, showing a simple and direct plan in compact form, of one storey only.

C. A more original plan without passages, built of brick, with American slate roof and 10 feet ceilings, and having the joinery finishings of Queensland pine. A second storey contains two attic rooms.

The detached Australian cottages, designed by Mr. W. A. M. Blackett, F.R.V.I.A., and illustrated in Fig. 180, show a compact treatment of plan to meet a peculiar situation, light being impossible from the outside boundaries of site.

The five rooms are well grouped and lighted in each case, with red brick and rough-cast treatment of fronts,—the plan having considerable resemblance to some which have already appeared in Volume II. when considering the planning of English cottages.

In Australia the villa type of building has found strong demand, and the phenomenal growth of the suburbs of the larger towns has led to the erection of vast numbers of one-storey houses. The terrace house that in the earlier days met with more public favour has decreased before the keen demand for detached residences surrounded with garden land.

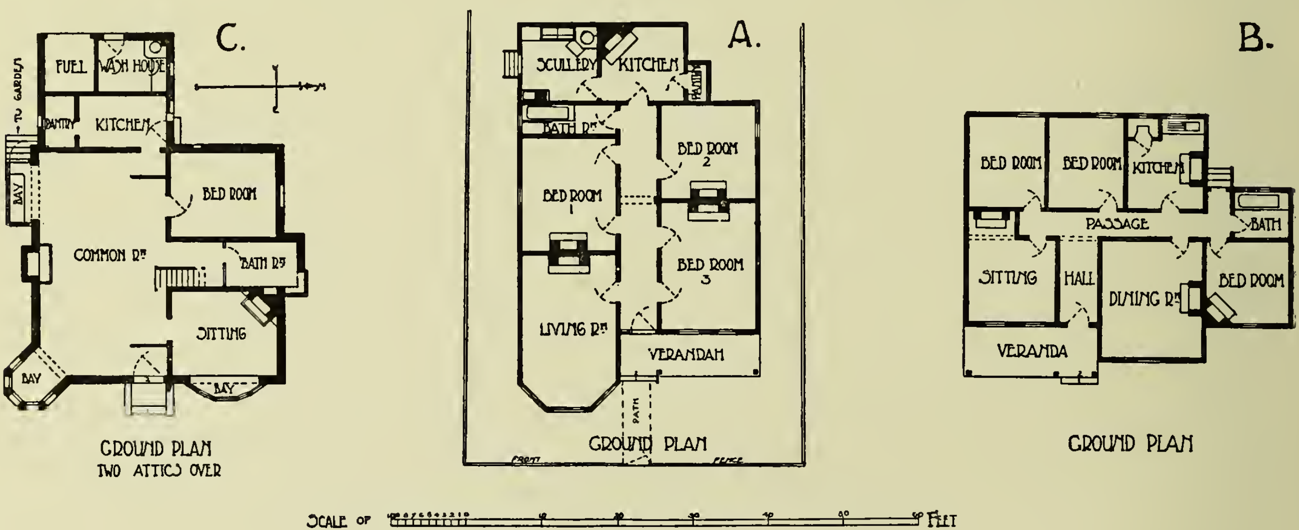


FIG. 179.

Australians as a people have a strong liking for the one-storey residence, and houses costing as much as £5000 are often planned on one floor.

In the plans here illustrated we have in the house at Toorak, Victoria (see Fig. 182), of which Messrs. Godfrey & Spowers are the architects, a villa of this class, with generous main apartments having 15 feet high ceilings, with verandahs along the north and east (the sunny) elevations; the "sitting out" on the verandah being quite a considerable part of Australian home life, especially during the hot summer months. This type of planning leads naturally to the general division of the house broadly into wings as here shown, such as the main wing containing a large cool hall

serving the principal rooms ; the bedroom wing for the family and visitors, with adjuncts of baths, etc. ; the kitchen and servants' wing, a complete establishment, with bed and bathrooms ; and a detached building for laundry, dairy, etc. This is an interesting extension of the system of departmentalising as found in the larger English houses (see Vol. I.). The opportunity for the

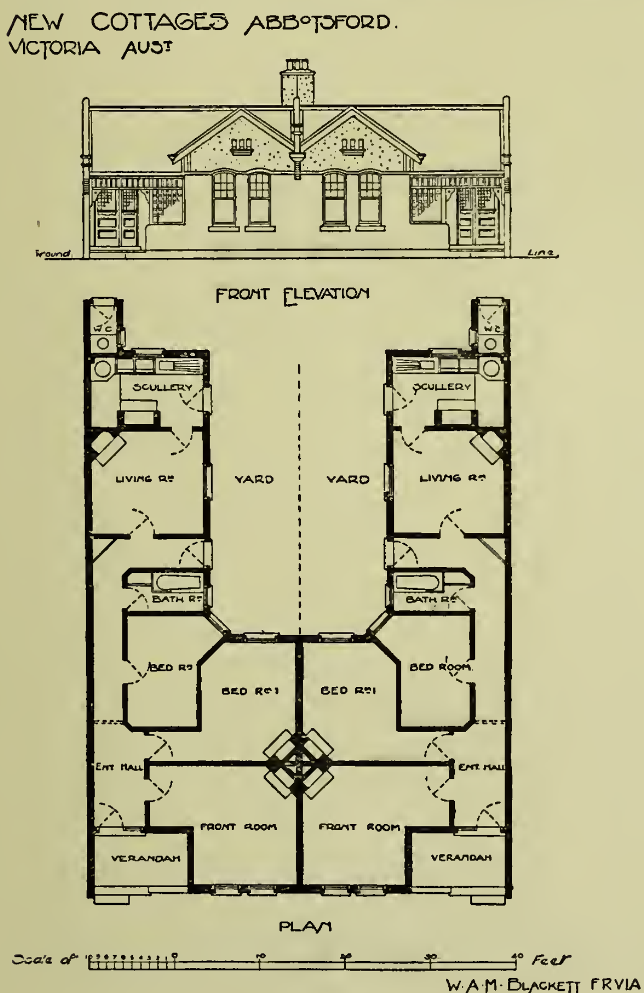


FIG. 180.

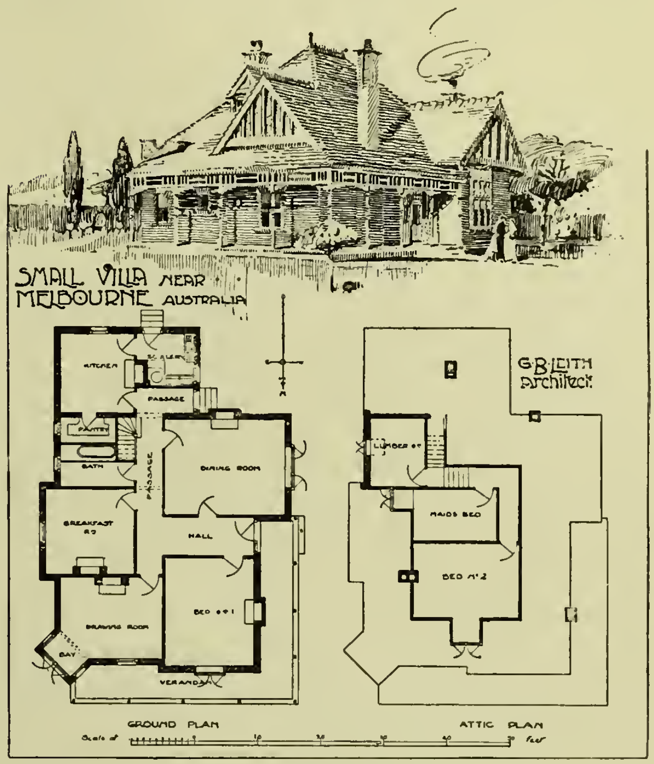


FIG. 181.

top lighting of passages, which the single-storey plan affords, is largely taken advantage of.

A villa plan of a smaller type is shown in Fig. 183, of which Messrs. Oakden & Ballantyne are the architects. This villa gives well thought out accommodation, and is so broken up as to induce general picturesqueness of mass.

In the small villa near Melbourne, designed by Mr. G. B. Leith (see Fig. 181), we have a compact little building for a small family, in which use has been made of the steep tile-covered roof to introduce some attic rooms.

The bungalow shown in Fig. 184, and designed by Mr. R. S. Dodds, A.R.I.B.A., illustrates the type of planning required in the sub-tropical climate of Brisbane, where the native woods are very largely used for domestic building.

Queensland is altogether very rich in beautiful timbers, and the market is well supplied with woods both for structural and ornamental purposes, which enter largely into domestic building in the State.

The conditions of Brisbane are such that open varandahs and open doors to catch the sea breezes are an absolute necessity for many months of the year, and these requirements have been worked into this plan, which makes full provision for open-air life shaded from the fierce heat of the sun.

The building is supported on hard-wood blocks, sunk into the ground and capped wlth inverted galvanised iron plates to prevent the destructive inroads of white ants into the structure. The walls are framed of hard wood and covered externally with hard-wood weather-boards, left virgin to weather a silver grey. The verandahs are enclosed with a wooden railing 3 feet high, and have the upper portions filled in with vertical wooden louvres working on steel pins. These are about 4 inches by ½ inch, and when closed completely exclude the glare of the summer sun. The roof is double, having a wood lined ventilated space under the galvanised iron covering. The internal walls are mostly of native wood panelling stained and wax polished, the floors being of hard wood.

The beautiful semi-tropical foliage of Queensland makes an admirable setting for the houses of this part of Australia.

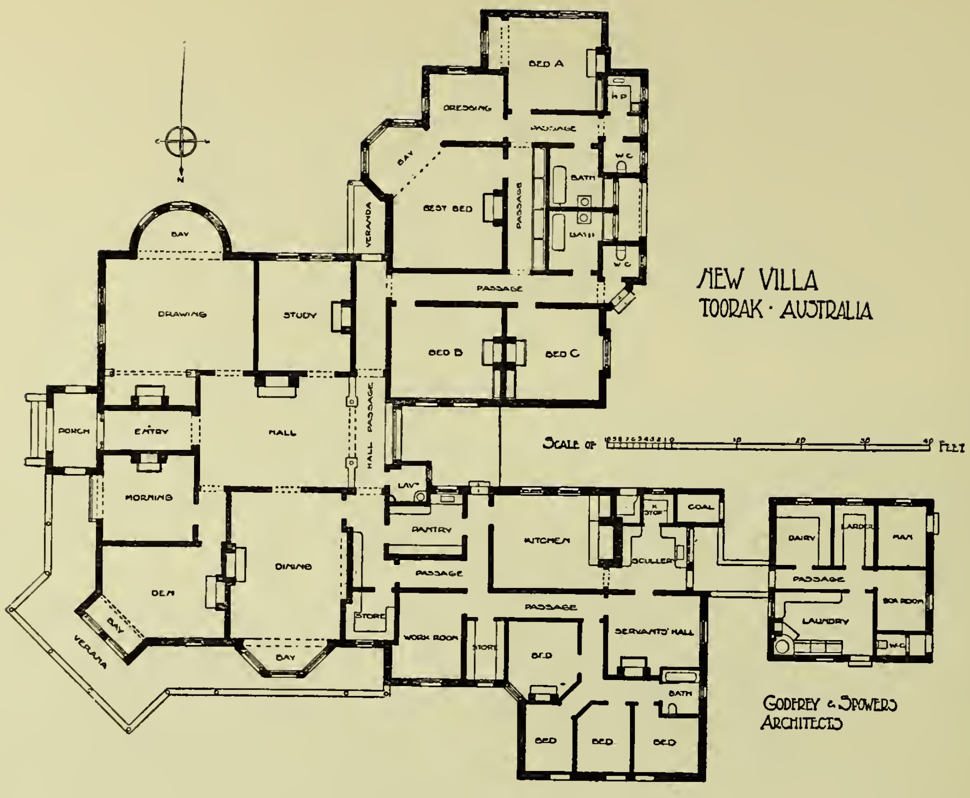


FIG. 182.

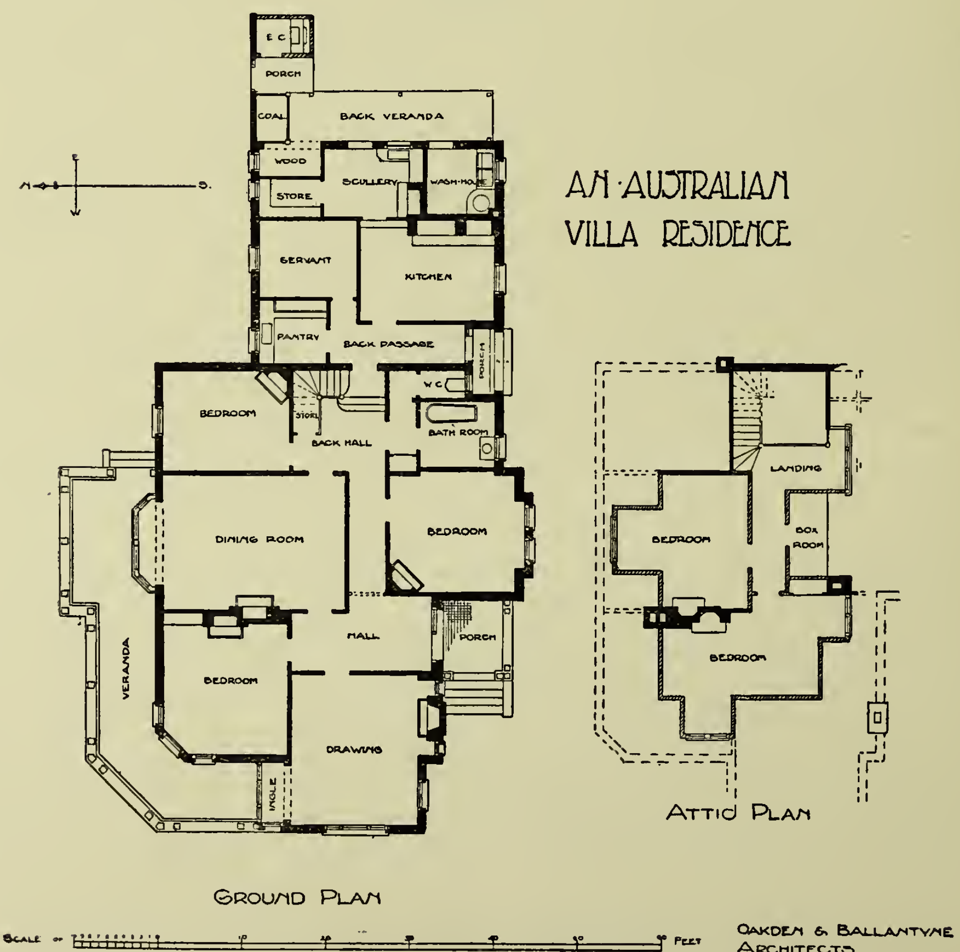


FIG. 183.

A general plan (Fig. 185) and perspective view (Fig. 186) is given of a carefully considered residence situated on the picturesque heights of Strathfield, near Sydney, designed by G. Sydney Jones, A.R.I.B.A., showing an admirable system of arranging the garden and the surroundings at the same time as the house, thus securing harmony of the whole. In the planning some attempt has been made to avoid the conventional the introduction of numerous verandahs, terraces, balconies, and exit doors and windows, while creating a well-balanced mass showing considerable character. The walls are constructed of golden brown bricks up to the first floor level, and above that they are hung with red wood shingles on brick nogging, the roof being covered with oak shingles.

The country residence shown in Figs. 187 and 188

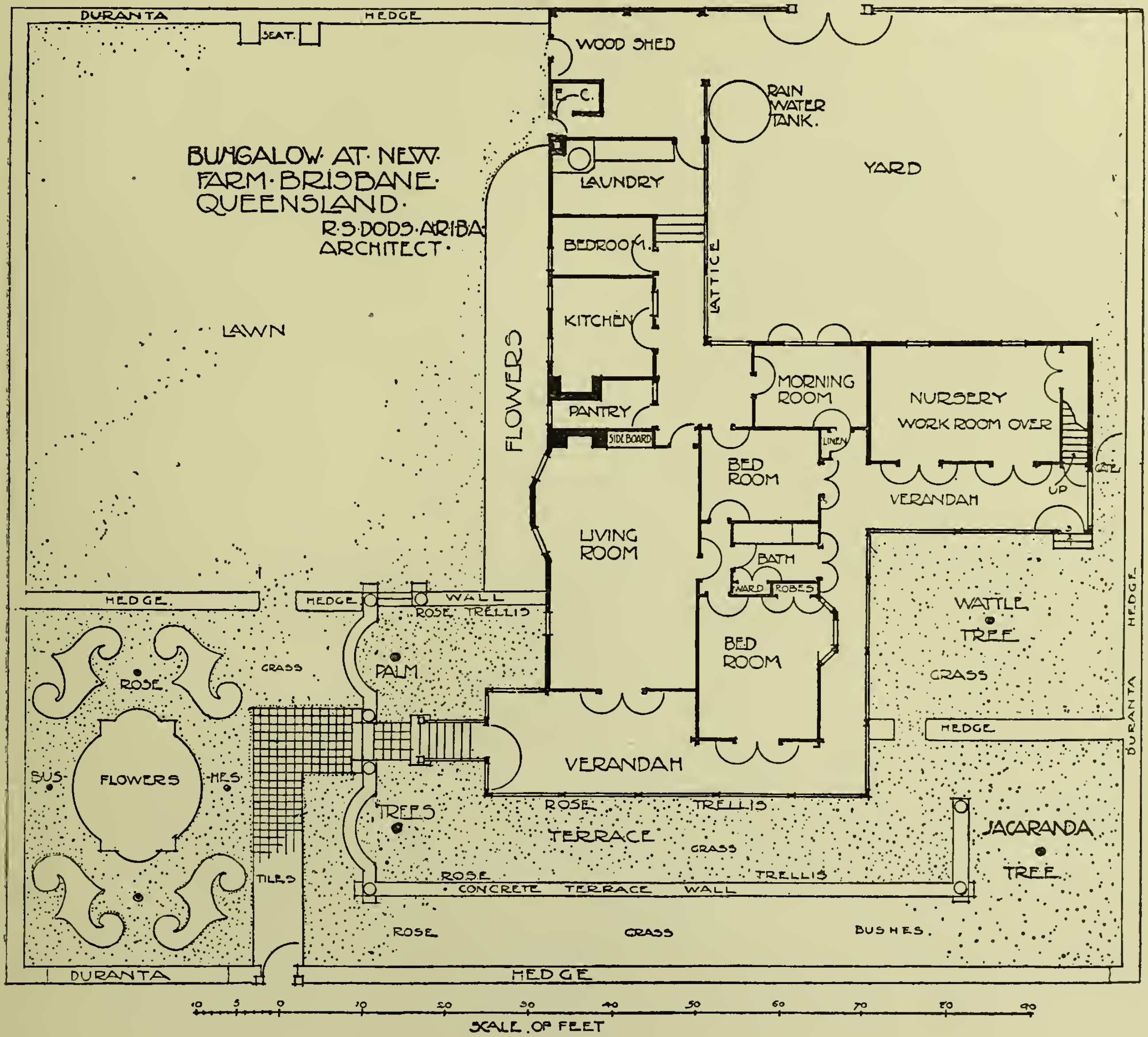


FIG. 184.

drawing-room, which has in this plan given way to an extension of the inner hall, so that together they make a large cool saloon with tiled floor in the centre of the house, thus creating a roomy common room. On the first floor are a large lounge-room and a number of large bedrooms and broad balconies, with a studio and workroom in the tower.

The plan well shows the admirable quality of providing for the semi open-air life of a warm climate by has been recently erected from the designs of Messrs. Sydney Smith & Ogg, in a pastoral district remotely situated from the sources of building material supply. Opportunity was taken of the deposits of bluestone in the neighbourhood to quarry sufficient stone for the general walling work, the quoins and arches being of brick. The plan shows rooms of generous dimensions, the hall reaching up to the full two storeys of height. A billiard-room is looked upon as a very necessary adjunct

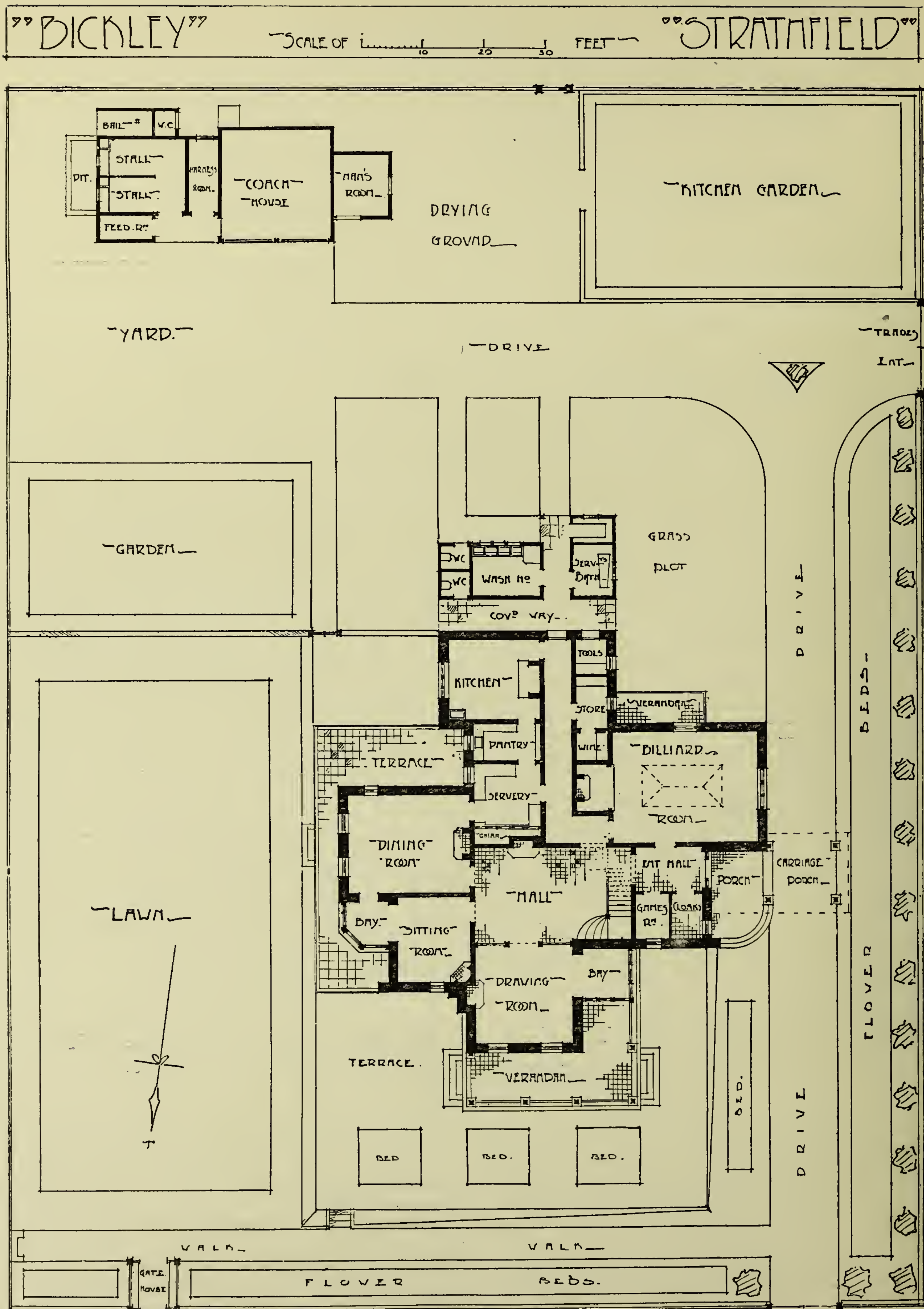
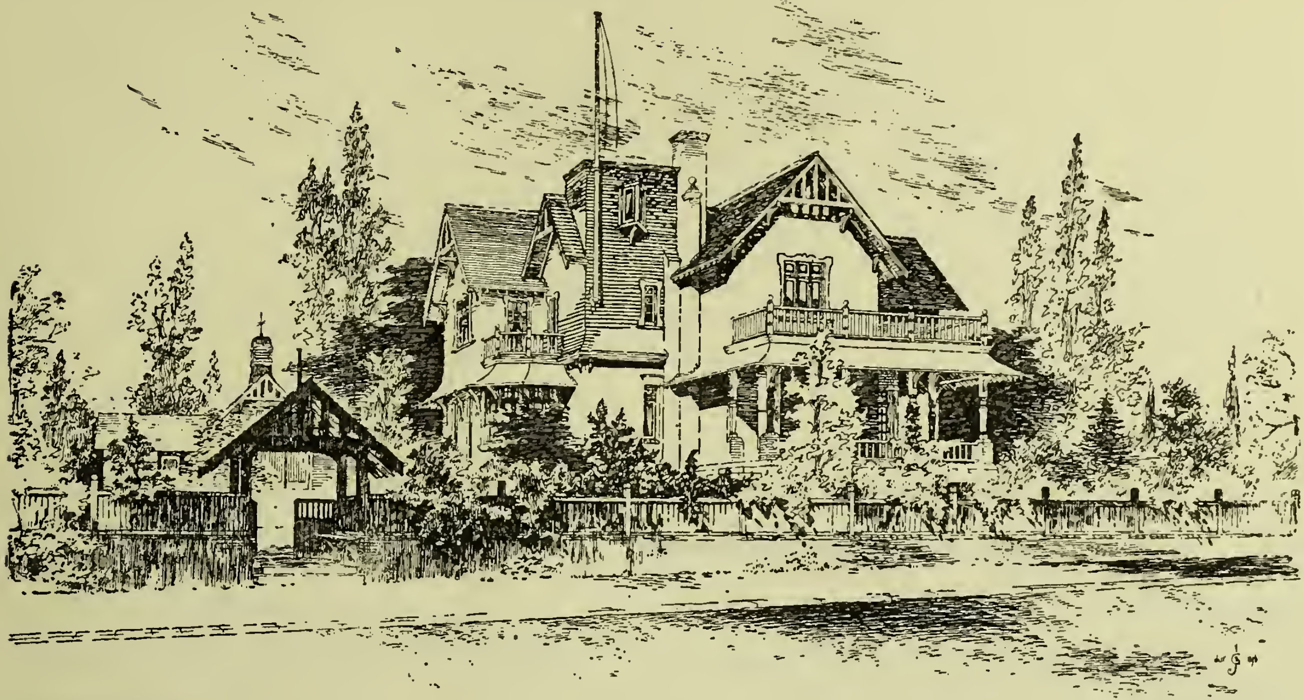

"BICKLEY"
SCALE OF FEET
10
20
30
"STRATHFIELD"
BAIL
W.C.
STALL
STALL
PIT.
HARNESS ROOM.
FEED RM.
COACH HOUSE
MAN'S ROOM.
DRYING GROUND
KITCHEN GARDEN
YARD.
DRIVE
TRADES ENT.
GARDEN
WC
WC
WASH HO.
SERVTS BATH
GRASS PLOT
COVD WAY.
TOOLS
KITCHEN
STORE
VERANDAH
PANTRY
WINE
BILLIARD ROOM
TERRACE
SERVERY
CHINA
DINING ROOM
ENT. HALL
PORCH
CARRIAGE PORCH
HALL
GAMES RM.
CLOAKS
BAY
SITTING ROOM
DRAWING ROOM
BAY
LAWN
TERRACE.
VERANDAH
BED.
BED
BED.
BED.
DRIVE
DRIVE
FLOWER BEDS
WALK
WALK
GATE HOUSE
FLOWER BEDS.

Fig. 185.

of the isolated house of this class, while the distinctly Australian preference for ground-floor sleeping apartments is seen in the rooms abutting on to the broad verandah. Generous storage is also required in country houses, and this has been supplemented in this case by a cool basement room. The servants quarters are so planned as to be cut off from and yet in touch with the main apartments, and the tower, though generally looked upon as a purely architectural feature, is often in these houses a very important look-out in times when the devastating and often fatal bush fires sweep the country. The height of the ground-floor rooms is 12 feet and of the first-floor apartments 11 feet. The lighting is by acetylene gas,



"BICKLEY," RESIDENCE OF MRS. E. LLOYD JONES, STRATHFIELD.

G. Sydney Jones. Architect. SYDNEY.

FIG. 186.

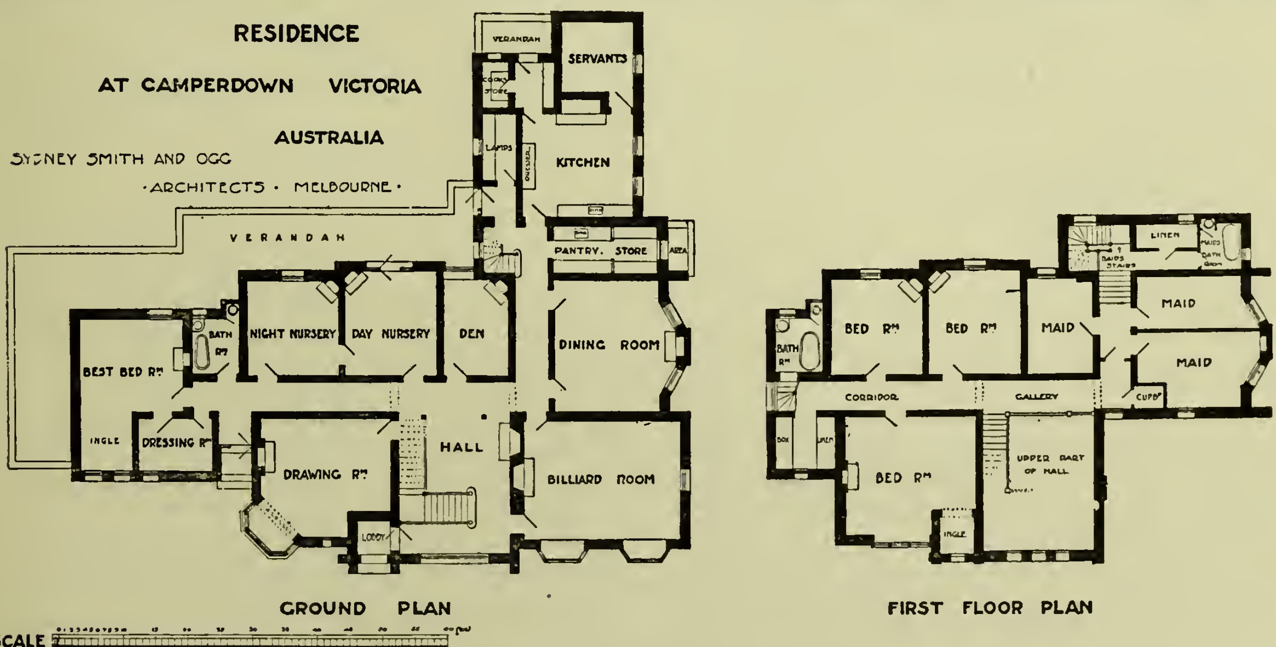


FIG. 187.

and the sewerage is disposed of by the septic tank system.

Fig. 189 shows a large modern Australian country house, "Yalla-y-Poora," erected in the western district of Victoria from the designs of Messrs. Tombs & Durran. Liberal accommodation is provided in an L-shaped ground-floor plan fronted by a terraced verandah extending along the north-east front. From the verandah the hall is entered with fronting staircase and retiring-rooms to the right and dining-room to the left, the kitchen offices and servants' sleeping quarters being in the south-east wing. The first floor is arranged with one stair only, as servants have ground-floor accommodation, the various rooms on the north being well served with a wide balcony. The walls are of locally quarried stone.

The house shown in Fig. 190 is a doctor's town house situated on North Terrace in the city of Adelaide, South Australia, and occupying a north-west corner site; but town houses, as understood in England, are little known in Australia. This building, designed by Messrs. Garlick & Jackman, has given opportunity for special skill in arranging for two entrances, the medical one to the side street and the main entry from North Terrace. The medical rooms, consisting of consulting-room with examination-room and with two waiting-rooms to the south of the entrance passage, are self-contained and cut off in a measure from the dwelling house, though the patients' entrance is quite as easily reached by the servants as is the main doorway. The private entry is under a verandah, which protects the walls from the fierce northern sun, and through a small hall to the high staircase hall which serves the drawing-room having a northern aspect and dining-room with an eastern aspect (west being invariably hot); advantage being taken of eastern aspect generally for kitchen offices. The first floor contains good bedroom accommodation with cut-off servants' apartment. There is a naturalistic breaking up of the plan which finds picturesque expression in the elevations, and small balconies are provided off the bedrooms, a provision much needed in such a hot climate as Adelaide. The walls are of red brick, and the roof of imported slates, the woodwork being green and the dressings buff in colour, producing a pleasing harmony.

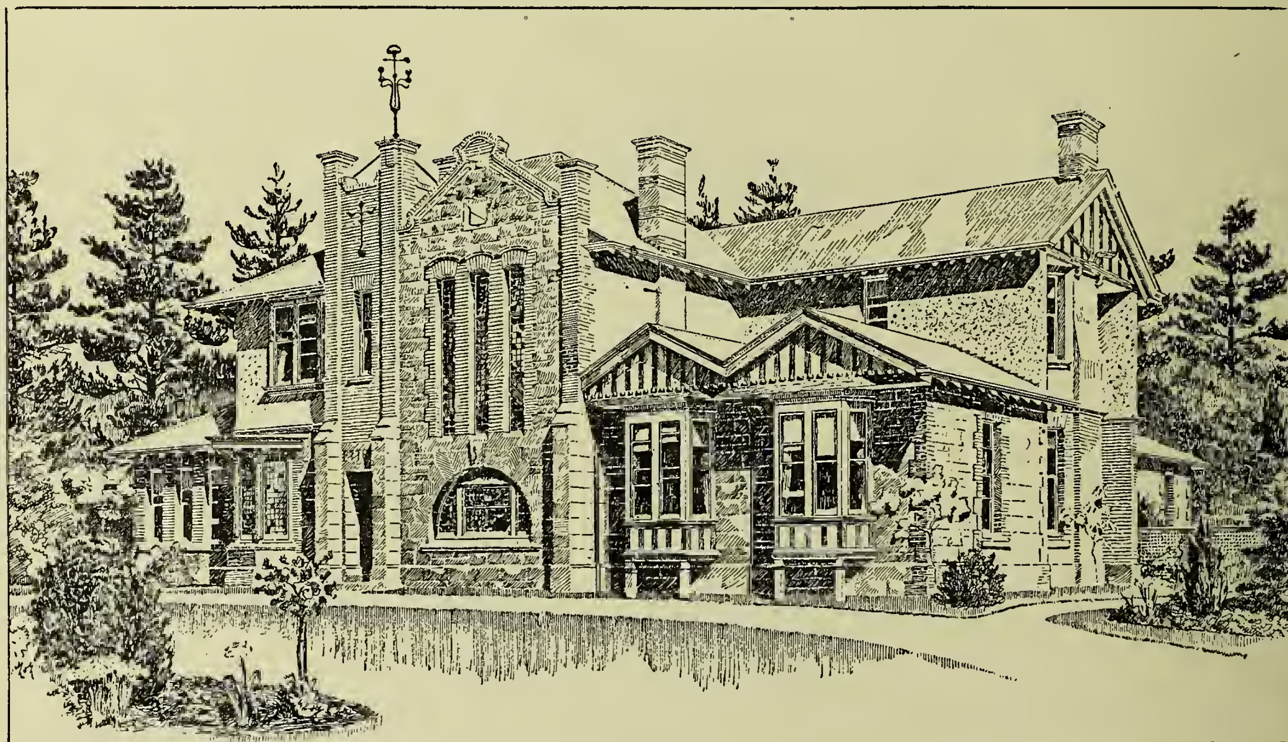


FIG. 188.

The flats, shown in Fig. 191, have been recently built, and are the first of their kind erected in the city of Melbourne. They comprise a large and commanding block of buildings in the main street. They are six storeys in height with sub-basement. Professional chambers are planned in the front block on either side of the central entrance, and embrace rooms on the ground floor and in basement for doctors, dentists, etc. Those facing internal areas are successfully lighted by internal mirrors. The central entrances give access to the residential chambers, which are entirely separated from the professional chambers.

The intention of the plan is to provide for three classes of tenants—or rather, to give tenants their option of the following:—

1. They could provide entirely for themselves and keep their own servants.

2. Or have their meals served in their own rooms from serving pantries on each floor served by electric lifts from the general kitchen.
3. Or take their meals in a general dining saloon.

About thirty well-lighted rooms are provided in the basements for servant and staff. There is a steep fall of land from front to back, making the basement practically a ground floor at rear. The suites range from two rooms, bath and w.c., to 11 rooms and conveniences. Balconies to Collins Street give well

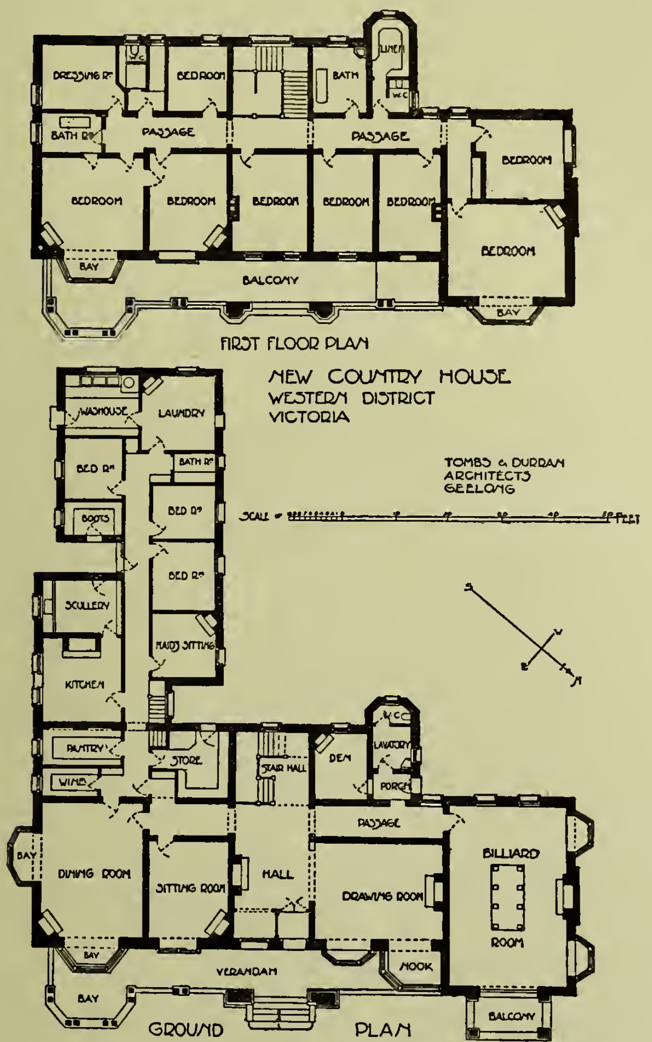


Fig. 189.

separated open-air accommodation. Electric lifts are fitted throughout, two being for passengers and six for food and parcels. Iron escape stairs are constructed outside at rear, and the corridor floors are fireproof. There is a roof garden over the front block. The general finishing is plain but in good taste, the whole of the treatment being in the new art manner, as also is the front, which is well balconied and with good shadow recessing, successfully surface treated in stucco. The architects for the work are Messrs. Inskip & Butler.

Shops

The Australian shop, if it be situated with a northern or western aspect, is invariably characterised by a permanent verandah, extending right over the public footpath with supporting posts at the curb. These structures are requested by municipal bye-laws, and in some of the cities are required by law, to be of one uniform design and construction. The eye, therefore, becomes familiar with the long lines of covered-in footpaths which, while giving protection to the pedestrian, also saves the tradesman's goods from the damaging influences of direct sunlight.

While in the older shops the heavy wood-framed portable shutter is now and then seen, there is a very marked tendency to entirely dispense with closing-in devices of any kind. The light iron railing, and the iron or wood revolving shutter are fast giving way to this new order of design, the entirely unprotected window.

The type tends more and more towards the most open front possible on the ground floor, with glass kept down to within a few inches of footpaths, with nickel, copper, or brass-covered sash bars, and polished marble-covered pilasters. The device has been also adopted in certain cases of carrying the whole of the heavy superincumbent brick or stone structure of even large business premises entirely upon steel uprights, where the building regulations allow such a form of construction. Where the older regulations remain, such as in the city of Melbourne, this form of construction is not at present allowed; and the superstructure has to be supported on stone or brick piers.

That the modern system of artificial lighting has had a marked influence upon shop design is apparent, and light has called for more light, with the result that the glint of polished metals, marbles, tiles, and majolicas enter largely into modern design.

The simple manner of lath and plaster ceiling has also been almost entirely superseded by wood, ornamental stamped steel, zinc, or fibrous plaster work, as it has been found that these materials give a much more permanent result than ordinary plaster, which has a tendency to crack and fall from its place under the wear and tear of the upper floors and the variations of temperature.

The detailed front of shop at Moonee Ponds, Melbourne, by Mr. G. B. Leith (see Fig. 192), shows a centre recessed entry treatment with low windows and stone dwarf wall. The side piers are also of stone, to take the girders above. The upper portion is treated in red brick and ornamental stucco.

The Dispensary, Geelong, designed by Messrs. Laird & Barlow (Fig. 193), shows the planning of a two-storey shop with private side entry to residential apartments.

There is a part basement under for storage purposes.

Good effect has been obtained in the front by the use of coloured glazed tiles. The oriels over are carried in

coke concrete, and some bold modelling marks the top pediment, which affords a pleasing sky-line.

Offices

The group of offices known as the Stock Exchange Building (Figs. 194 and 195), situated in Pitt Street, Sydney, was erected from designs by Messrs. Sulman & Power, of that city. The planning has been confined to providing large public and call-rooms, together with as much space for revenue production by letting as could be obtained.

This building was erected in conjunction with another which adjoins it, and a central mutual basement stair has been arranged, giving access to a mutual light area, which gives particularly good light to the basement offices. The entrance corridor has been made an attractive feature by the introduction of marble paving and a very fine dado of Australian marble. The front, though simply treated, is both good in colour (being built up of red brickwork and warm brown stone dressings) and effective in mass of light and shade.

The National Mutual Life Association Building, here illustrated in Fig. 196, shows the planning of a large city building upon a restricted site. The work is the production of Messrs. Wright, Reed, & Beaver, of South Australia, whose designs were selected in public competition. The building occupies a commanding site in the principal street of the city of Melbourne, having a frontage of 82 feet to Collins Street and 50 feet to Queen Street, the height from street level to top of corner turret being 140 feet.

The building comprises seven storeys and a basement (eight floors in all), and is of the most substantial character throughout, and replete with all modern conveniences. The basement contains offices to let, also strong-room, engine-room, and stationery-room for the use of the Association, with a private stairway to the ground-floor office. The Association's offices are on the ground floor. At the back of the hall, directly facing the entrance, are three passenger elevators. The first, second, third, fourth, and fifth floors are arranged as offices to let, each suite having strong rooms, etc., and each containing lavatory and other conveniences. The sixth floor is utilised for the board-room and other offices connected with the Association, and the seventh floor is devoted to caretaker's quarters, etc. All the rooms are large and lofty and thoroughly ventilated, special appliances being supplied for the extraction of foul air, in addition to which fresh air is conducted to each apartment, after being warmed in the winter weather and cooled during the hot months. The building is entirely of fireproof construction, the floors being of terra-cotta lumber and rolled steel joists. The two fronts are carried out in freestone on base courses of polished granite. The finishings of the

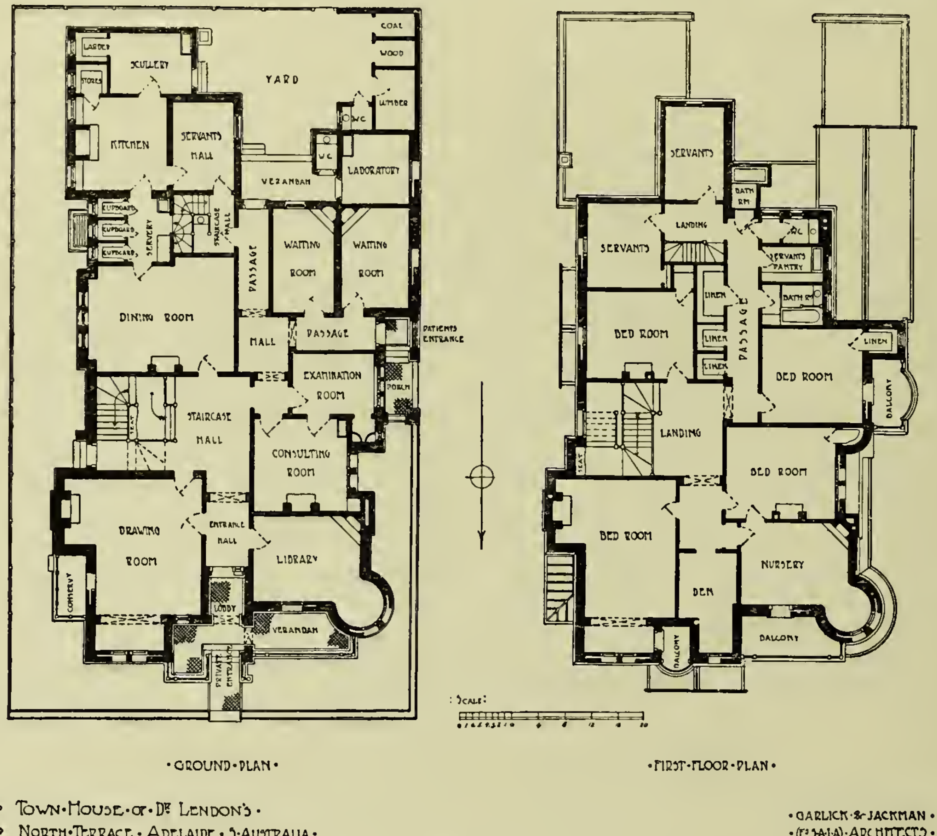


Fig. 190.

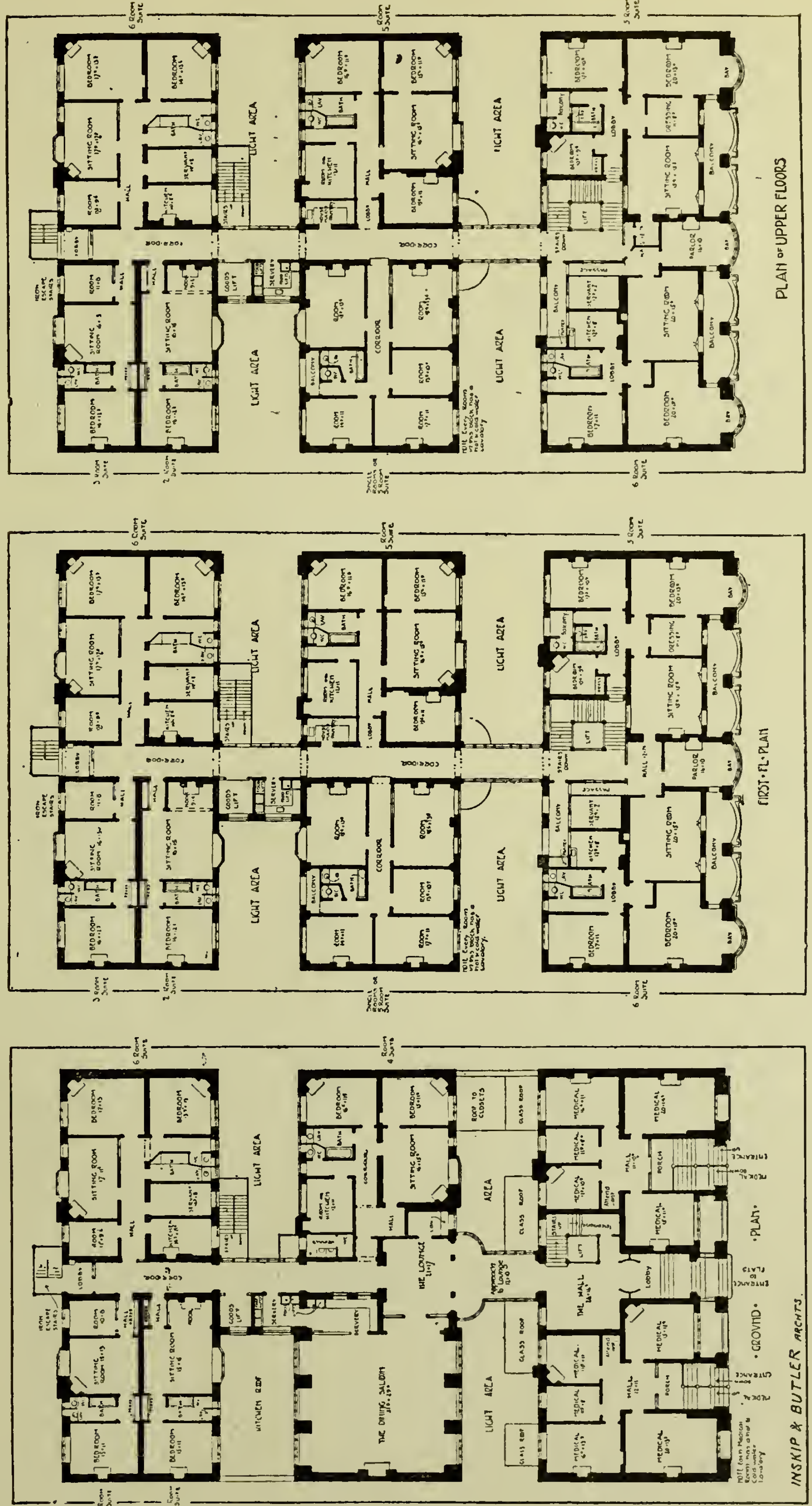

PLAN OF UPPER FLOORS
FIRST·FL·PLAN
·GROUND· ·PLAN·
INSKIP & BUTLER ARCHTS.

FIG. 191.

interior have been carefully designed, the woodwork of the ground floor being walnut and the floors laid with marble tiles and parquetry. The entrance hall is entirely of marble in different colours, and the staircase of marble up to the first floor, and the remainder in bluestone.

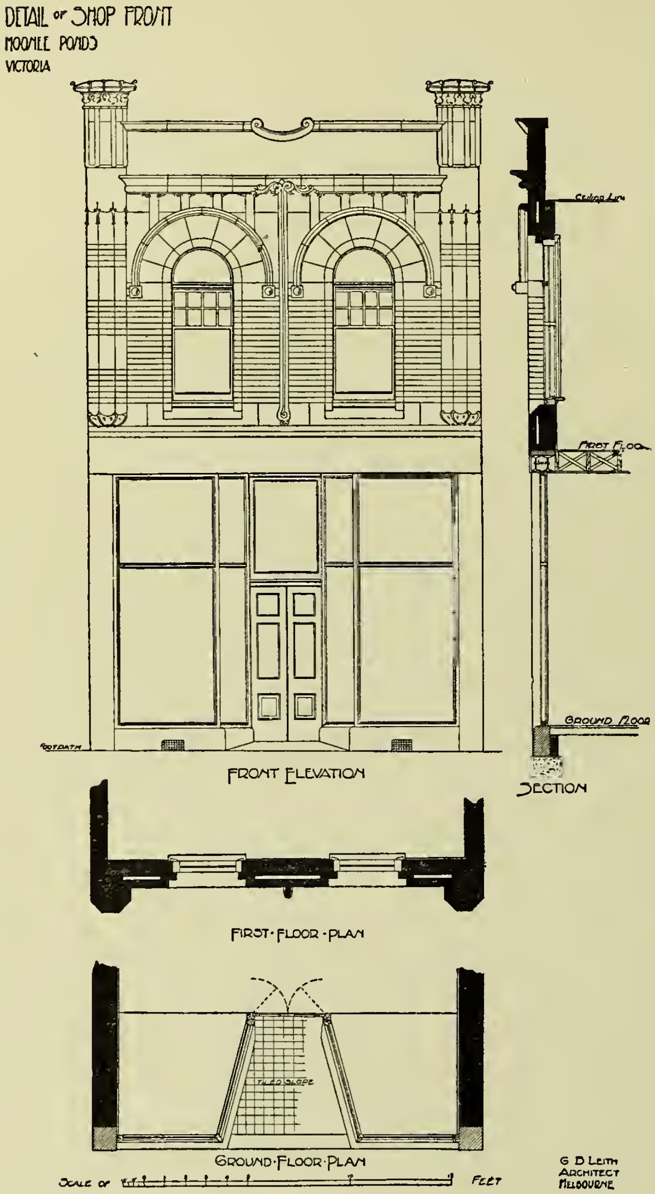


Fig. 192.

Fig. 193.

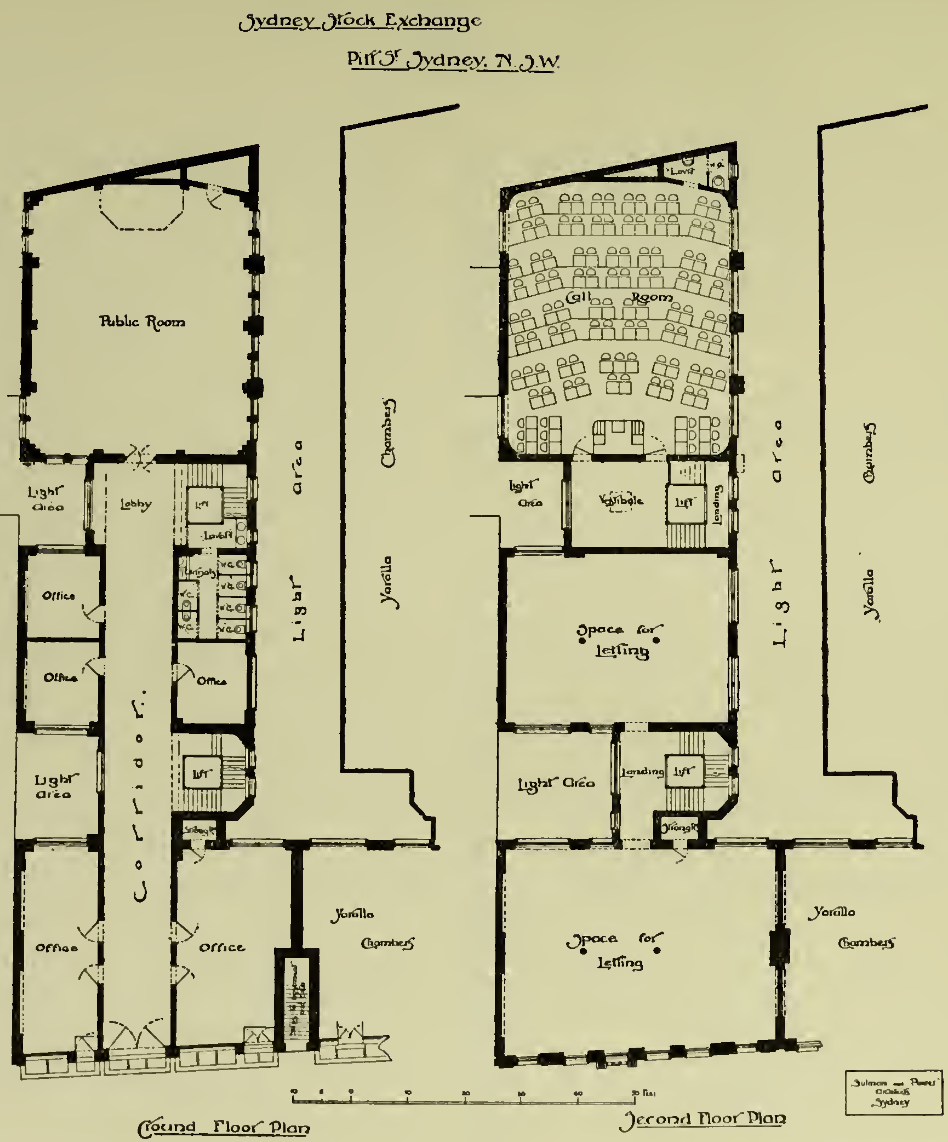


FIG. 194.

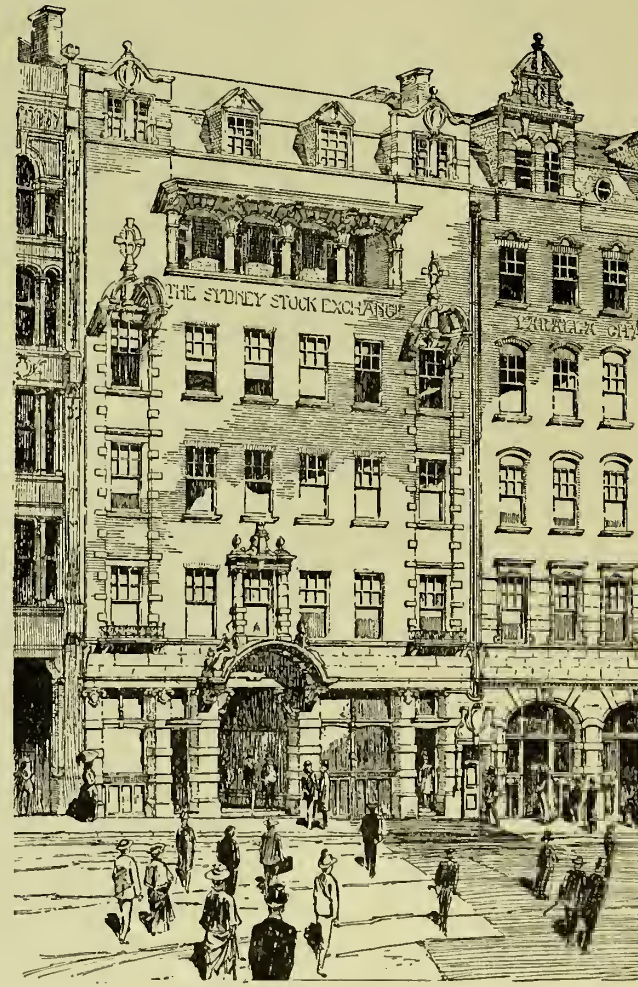


FIG. 195.

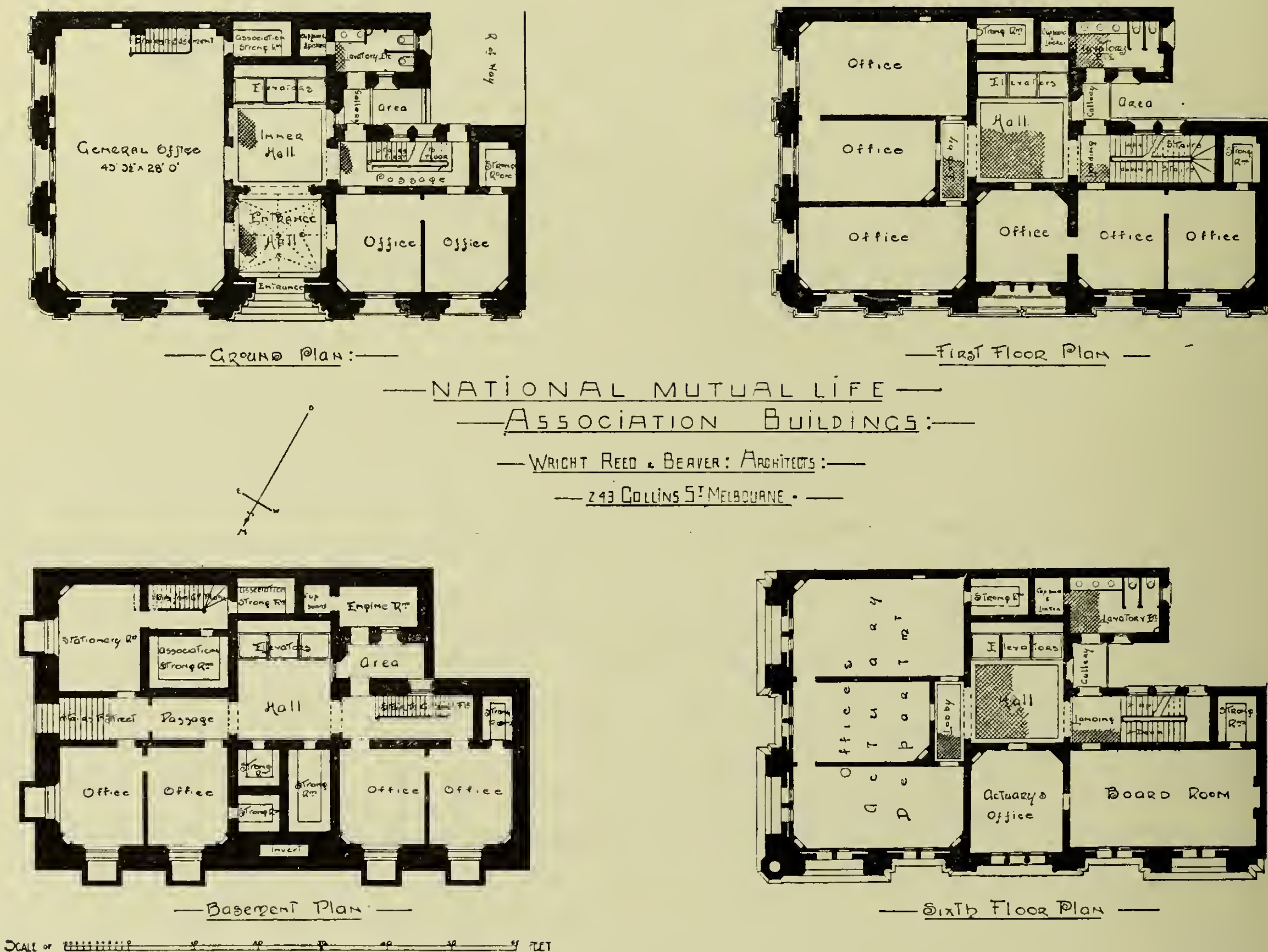

Ground Plan:
First Floor Plan
National Mutual Life
Association Buildings:
Wright Reed & Beaver: Architects:
243 Collins St Melbourne
Basement Plan
Sixth Floor Plan
General Office
Inner Hall
Entrance Hall
Office
Office
Hall
Area
Passage
Elevators
Stationery Rm
Association Strong Rm
Engine Rm
Board Room
Actuary's Office
Offices Actuary Depmt

Fig. 196.

CHAPTER III

PUBLIC BUILDINGS OF ALL KINDS

(*Contributed by R. J. Haddon, F.R.V.I.A., F.S.A.I.A.*)

Williamstown School (Fig. 197) is one of the latest type of Government infants' schools, designed in the Department of Public Works, and so planned as to give direct left light to all classrooms, which are fitted with dual desks, and have Hylos blackboard plates built to walls. The planning is almost identical with that of the English "hall" school, save that the classrooms are larger and the external doors are so arranged as to allow of scholars being marched out right through the hat and cloak-rooms; the large assembly hall, 50 by 30 feet, being centrally arranged. This building is of brick, with Stawell stone dressings, the roof being covered with Welsh slates, and the internal ceilings being of stamped zinc and the floor of Kauri (New Zealand) pine. The ventilation is conducted through metal inlets in walls, the general outlets being through Central Board of Health pattern exhaust vents above roof; the central hall outlets being through Boyle's vents in *flèche*. Heating, when required, is conducted by open fires, and the general internal finish is white.

Figs. 198 and 199 show a modern private hospital upon a limited city site, designed by Messrs. Sydney Smith & Ogg, architects, for Dr. William Moore, a leading Australian surgeon. Such a building has to conform to the requirements of the Central Board of Health, as also to the laws of the City Building Act.

The plan is broadly divided into three floors. The ground floor contains the consulting and administrative floor; the first floor being devoted to wards, and the top floor to operating-rooms and nurses' quarters. Owing to a rapid fall in the land to the south, storage and other offices are worked into a sub-basement.

The large number of single-bed wards required in a private establishment of this kind will be noticed, as also will the lack of through ward ventilation and of nurses' supervision rooms, without which even the smallest hospital would be incomplete in England. Exception might, from the English point of view, also be taken to the long ill-lighted and ill-ventilated passages, not always capable of cross ventilation or even of supervision.

The sanitary offices are air-separated in an eastern annex, though the approach to them is tortuous, and the elevator from this point serves all floors, as also a flat roof over southern portion of the building for the use of convalescents; from which elevated position a most extensive view is obtained over the city and beyond to the waters of Hobson's Bay. The back stair is so arranged as to not only serve the main floors, but a series of storerooms one above the other right up the full height of building, two in height equalling the height of an ordinary floor, thus saving considerable space; but it is badly lighted and unventilated. The general internal finish is plain, all corners being rounded. The operating-room is lighted by a great south window only, the owner preferring this to a top-lighted room. Escape stairs of steel boiler plate and wrought iron are provided at south end and on east side.

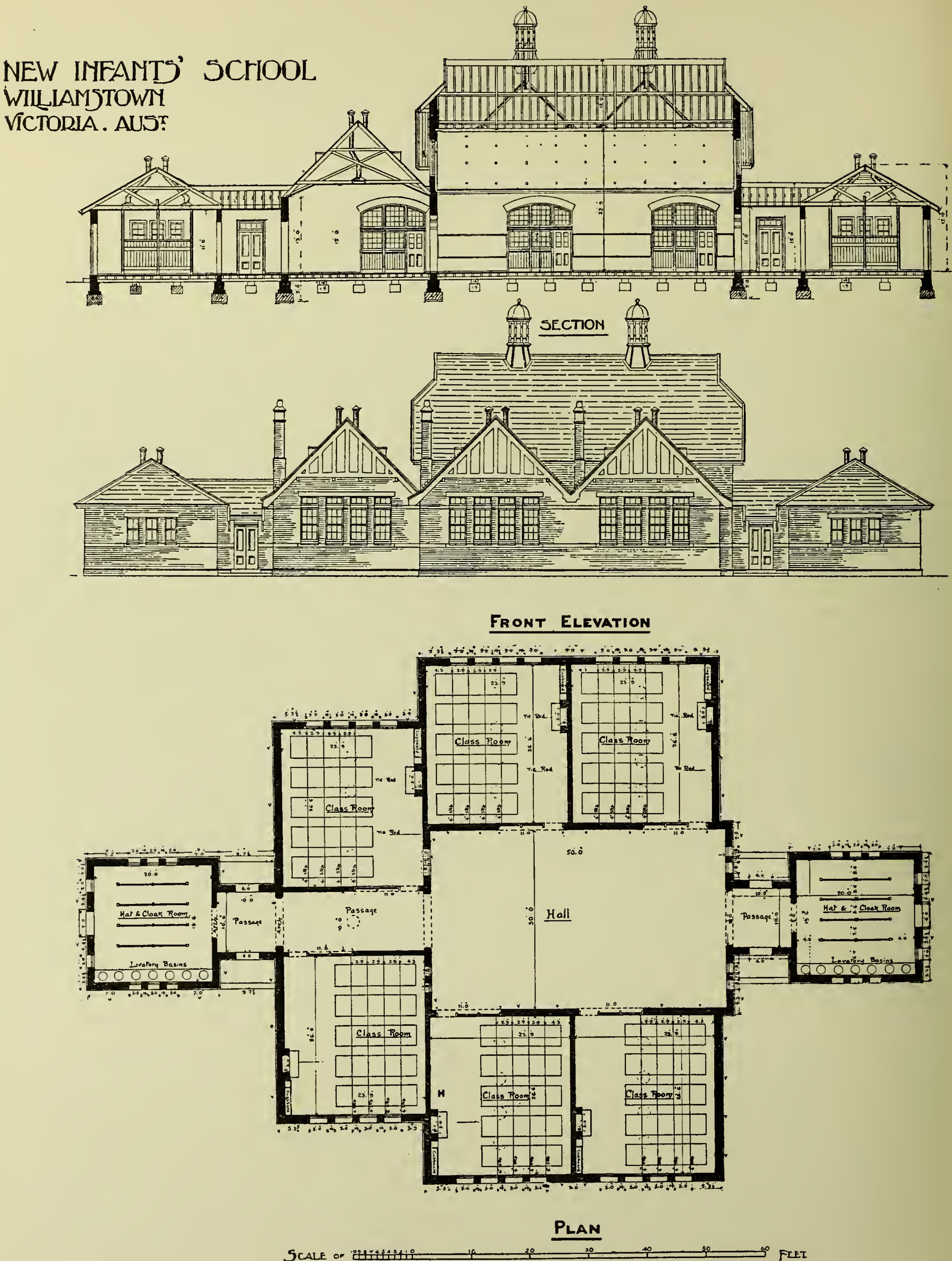
The general massing of design is restrained in character, and with simple lines and widely overhanging projections is seen to excellent advantage in a sunny climate.

The Walker Convalescent Hospital (Figs. 200, 201, and 202), designed by Messrs. Sulman & Power, occupies a site of some thirty-three acres of promontory on the Parramatta River, some seven miles from the city of Sydney.

This is a privately built and endowed institution for providing accommodation for the poorer class of convalescents who are not able to get away for necessary change upon recovery from illness. The plan therefore differs in many points from that of an ordinary hospital, and partakes more of the character of a large country house.

The building is approached from the river by a picturesquely designed water gate, with which is grouped a boat-house with smoking-room and balcony over. This feature adds considerably to the attractiveness of the architectural composition.

Passing through the water gate, the path leads directly up to the front administrative block, immediately to the rear of which is the "Recreation Hall" (Fig. 201), flanked right and left by two courts, with ambulatories around, from which are entered the patients' pavilions. Dining halls are planned to right and left, and are entered from the ambulatories, with kitchen offices placed between them. Children's and gardeners' cottages, laundry, and stables are scattered about the grounds (as shown by block plan, Fig. 200). Provision is also made for the erection of two more



NEW INFANTS' SCHOOL
WILLIAMSTOWN
VICTORIA. AUST.
SECTION
FRONT ELEVATION
Class Room
Class Room
Class Room
Class Room
Class Room
Class Room
Hall
Passage
Passage
Passage
Hat & Cloak Room
Hat & Cloak Room
Lavatory Basins
Lavatory Basins
PLAN
SCALE OF FEET

FIG. 197.

pavilions at a future date. The arrangements made for sheltered and airy promenades, and for direct and easy service, will be noticed, as well as the manner of dealing with the roadways (Fig. 200) and the screen of shrubs which is provided to the back entrance to the kitchen-yard (Fig. 201)—itself a rare and excellent feature.

At present, accommodation is provided for some 32 adult patients of each sex in the pavilions and for 16 children in the cottage.

The buildings are of red brick with stone dressings and Marseilles tiled roofs. The finishings of walls are in Keen's cement with rounded angles, the joinery to front administration and pavilions being in cedar, and that of the other offices in American pine.

The general plan of the Melbourne Public Library (Fig. 203) shows the large existing buildings fronting Swanston Street on the west, and passing along the whole of a city block to Russel Street on the east, and comprising an imposing entrance portico in the Corinthian style, leading into a spacious vestibule with flanking blocks used for museum purposes. On either side, passing through these, the Fine Art Galleries are reached.

The buildings facing Russell Street are planned as a Natural History Museum, surrounded on three sides by picture galleries containing the national collection.

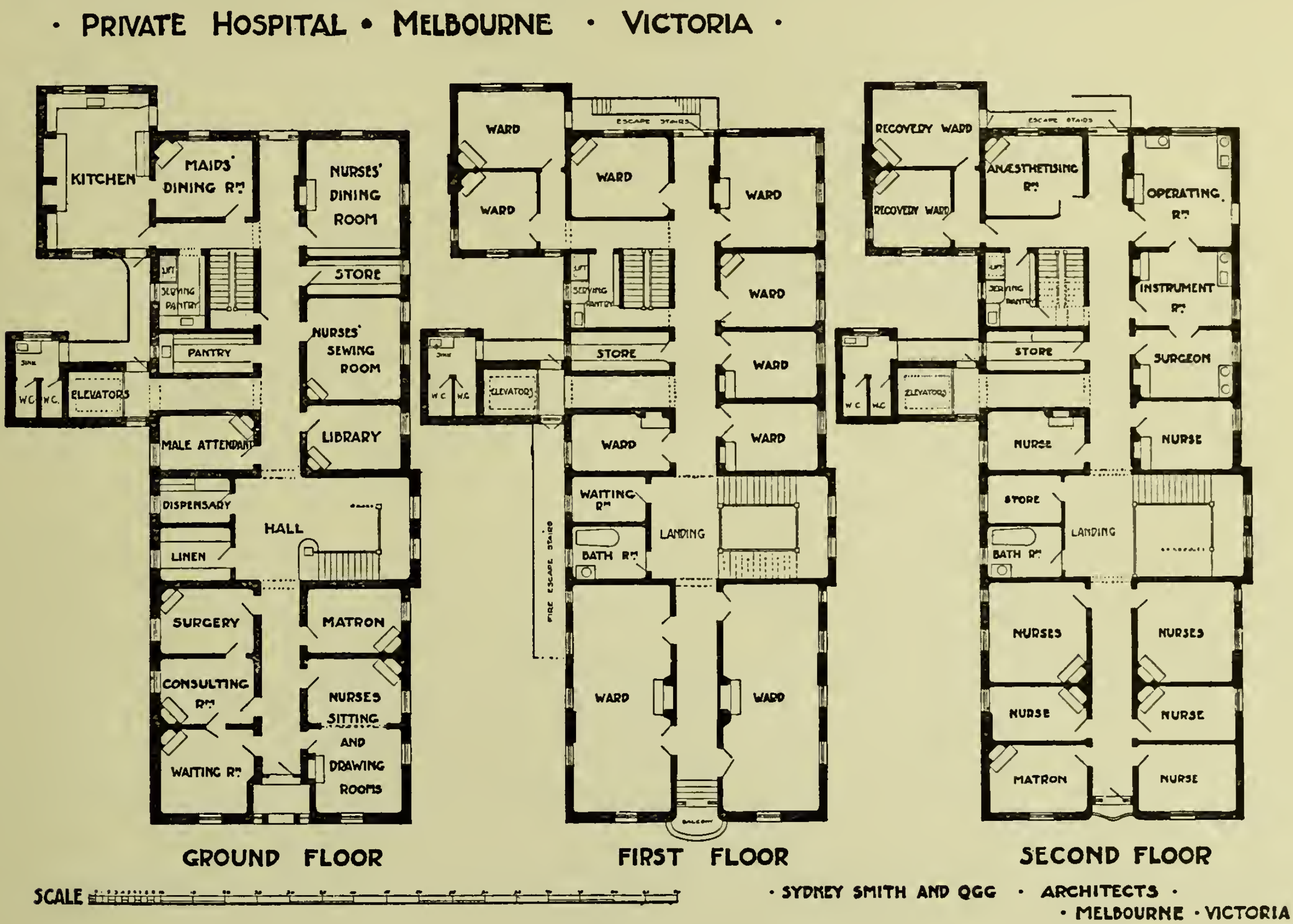


FIG. 198.

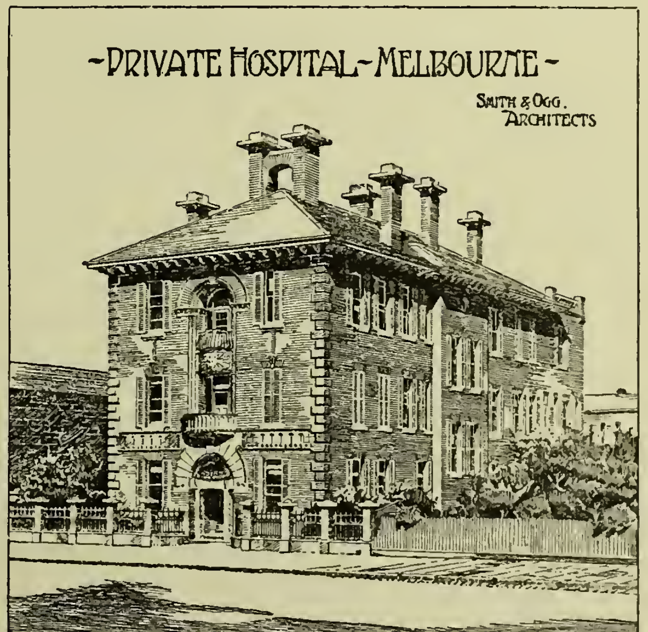


FIG. 199.

On the south side above the picture gallery are extensive art schools.

The library portion at present comprises the Queen's Reading Room, extending over the whole of the Swanston Street frontage, with returning wing over the south Art Gallery. It is proposed in the near future to erect the high round the apartment. The book stacks will be arranged around the room, entirely surrounding it, these being 8 tiers in height forming arched galleries around the great reading-room ; and the whole will be roofed with a flattened dome. The day lighting is arranged from roof as well as through gallery windows.

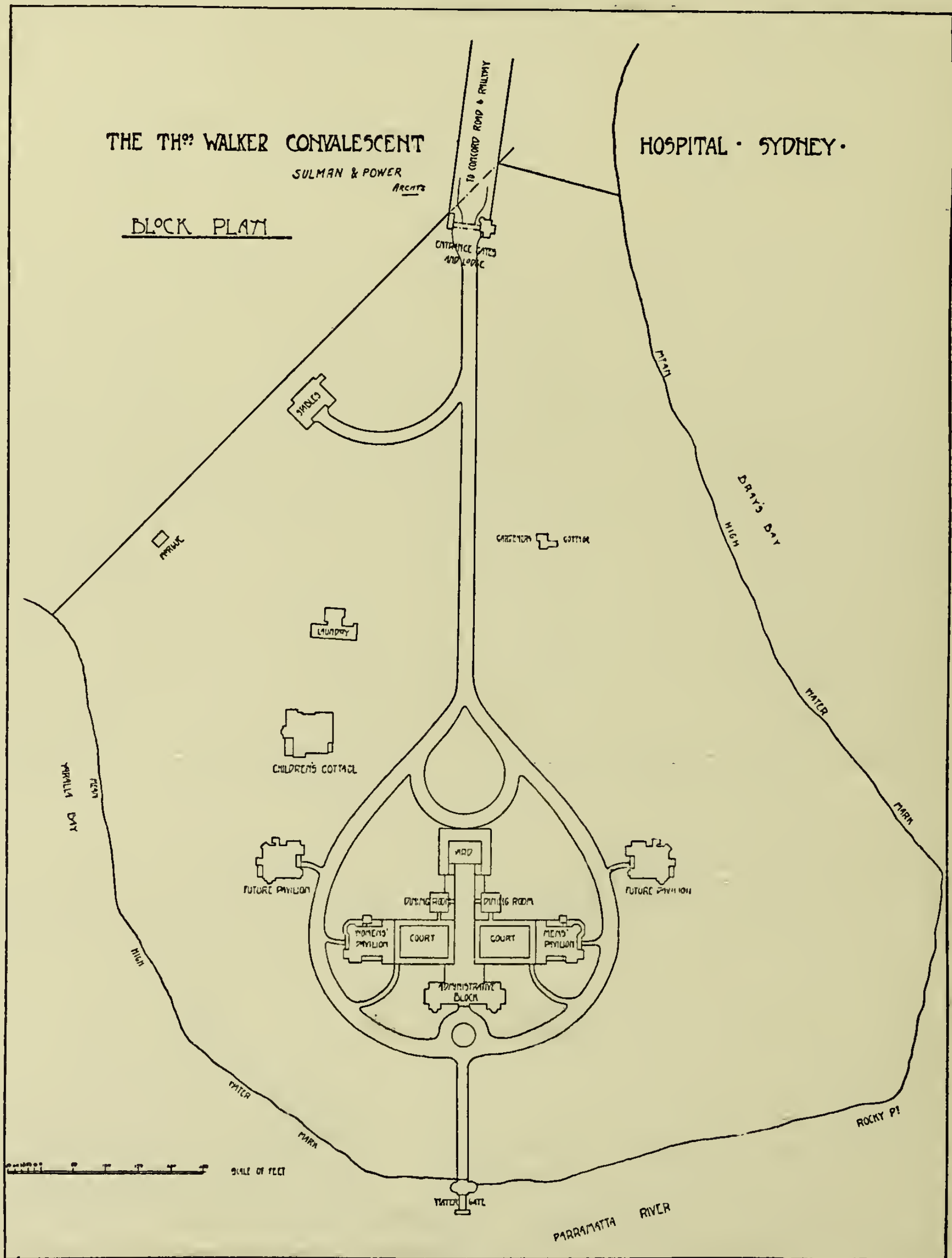


FIG. 200.

great octagonal reading-room which has been specially designed by the architects, Messrs. Reid, Smart, & Tappin, of Melbourne, to contain a million books. Planned on the lines of the Washington Congress Library, it will consist of a central floor to accommodate desks for 500 readers, with central book delivery from underground floor, the reference library forming a dado some 8 feet

The library is so planned as to prevent individual handling of the books other than reference books by the readers, the service being accomplished by special attendants only.

The first portion of these buildings has been erected of Tasmanian freestone, and the later portions with Stawell Victorian white freestone.

The Town Hall at Sydney (Fig. 204) is an exceedingly fine example of a monumental structure of this class, arranged on an open site so as to be accessible from all sides. The great hall is placed axially with the entrance, and has wide corridors to serve the auditorium down either side, as well as a great crush-room or

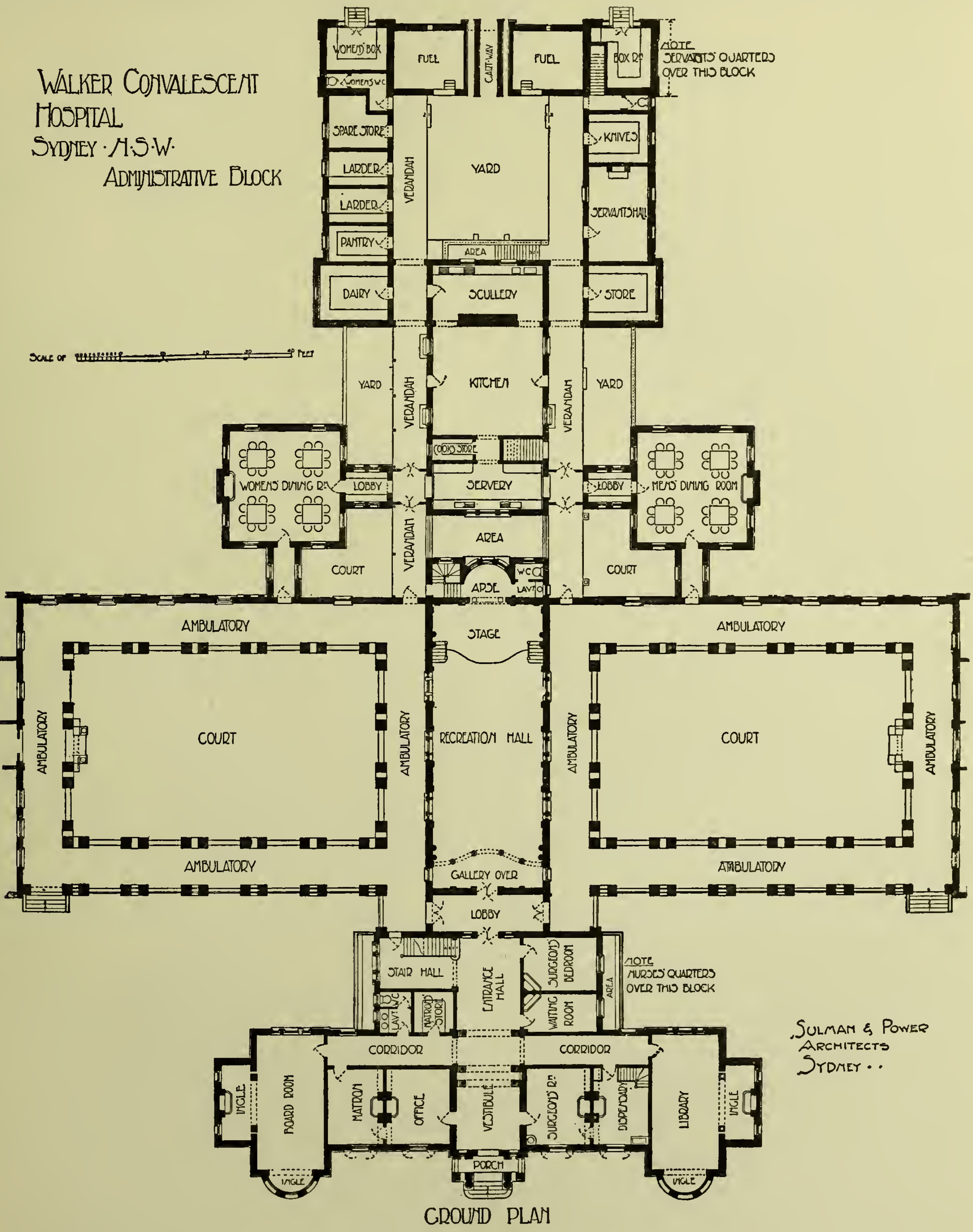


FIG. 201.

vestibule at the entrance end, round which these corridors are continued. The same corridors are made to serve the various administrative offices, which are arranged in suites much as was explained in connection with the Walsall Town Hall illustrated in Volume IV., though they are somewhat more disconnected in this instance, owing to the central introduction of the great Concert Hall. Besides the main front entrance there are also important means of access from each of the side streets, as well as actors' entrances to rooms beneath the platform and organ. Three main staircases, one on either side and one in front, give communication with

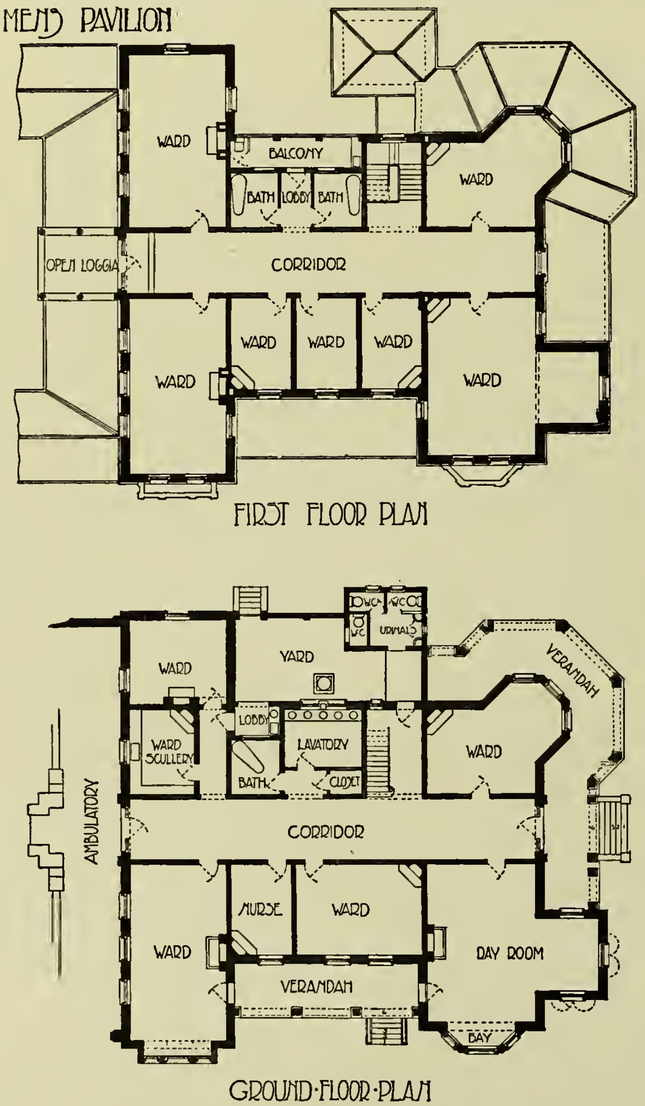


FIG. 202.—Walker's Convalescent Hospital, Sydney.

upper floors of offices and with the galleries. The plan is a symmetrical one, carefully laid out to give an opportunity for architectural treatment both externally and internally.

Under the main hall is another hall of almost similar dimensions, but only 20 feet in height, which is utilised as a supper and banqueting-room, while adjoining it are the kitchen and culinary offices.

The Shire Hall at Ballan, Victoria (Fig. 205) is fairly typical of the smaller class of Australian municipal buildings required in the country, such a building meeting the limited needs of the headquarters of the shire council and officials. This type of plan is some-

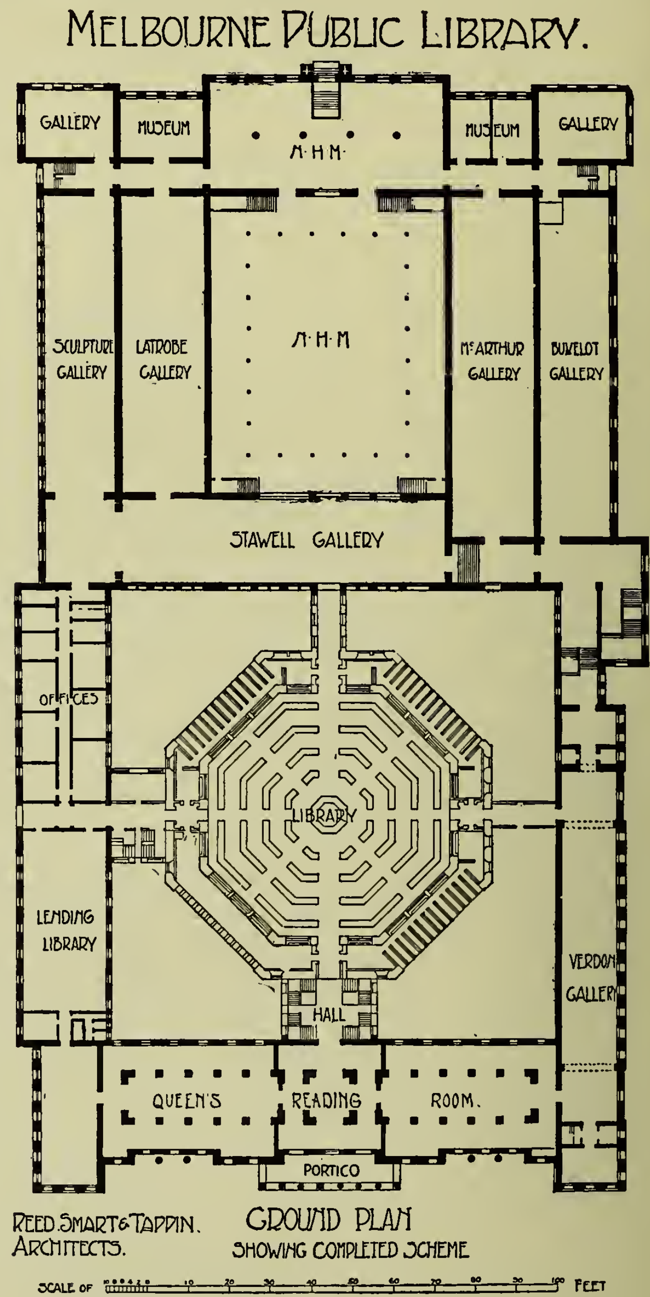


FIG. 203.

times supplemented with a public meeting hall at the back. Use is made of the loggia in front to give public access to the Council Chamber, while a corresponding corridor at the back serves for official intercommunication.

The capital cities of Australia being all within easy access of the sea, great enclosed sea baths have for many years held the public favour and supplied the

public demand. These invariably consist of a front administrative building leading into a great pile-driven, shark-proof, sea-water area, flanked with dressing-rooms. As some 40 per cent. of the total population

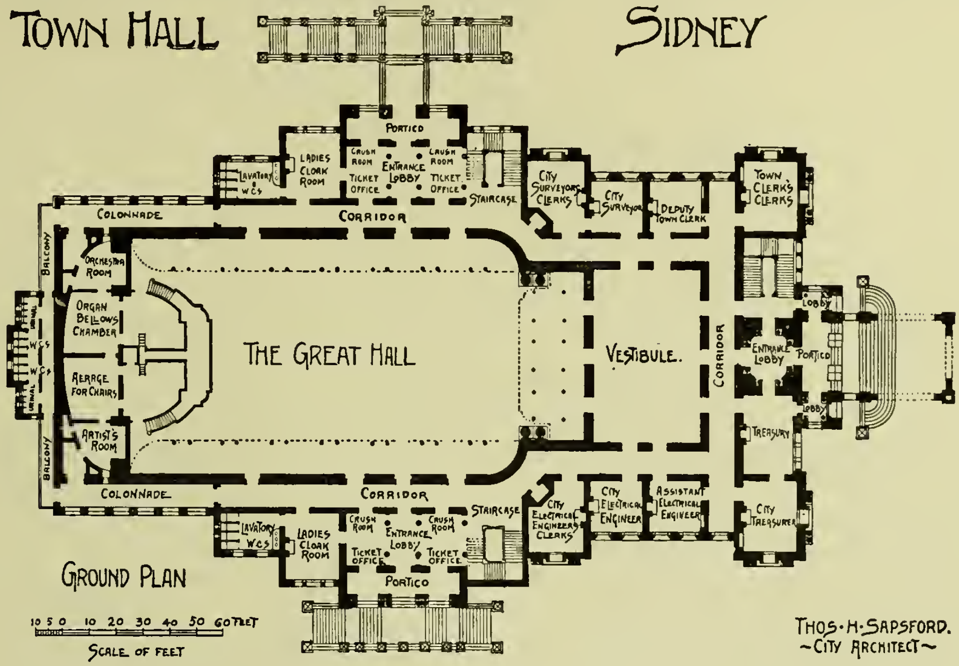


FIG. 204.

of Australia are dwellers in the capital cities, there has been but limited need for large inland public baths.

This type of sea bath upon a much smaller scale

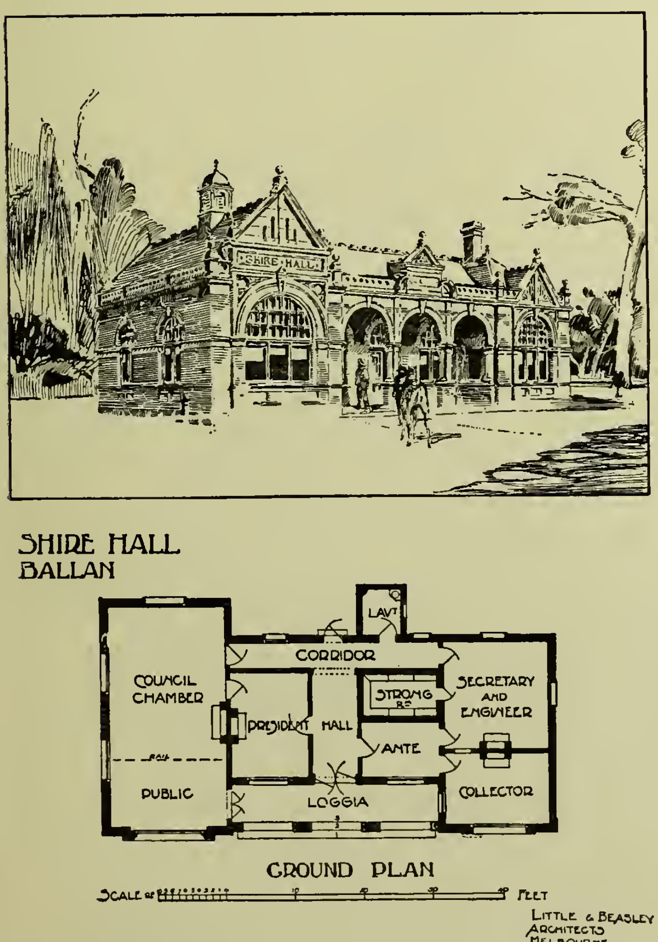
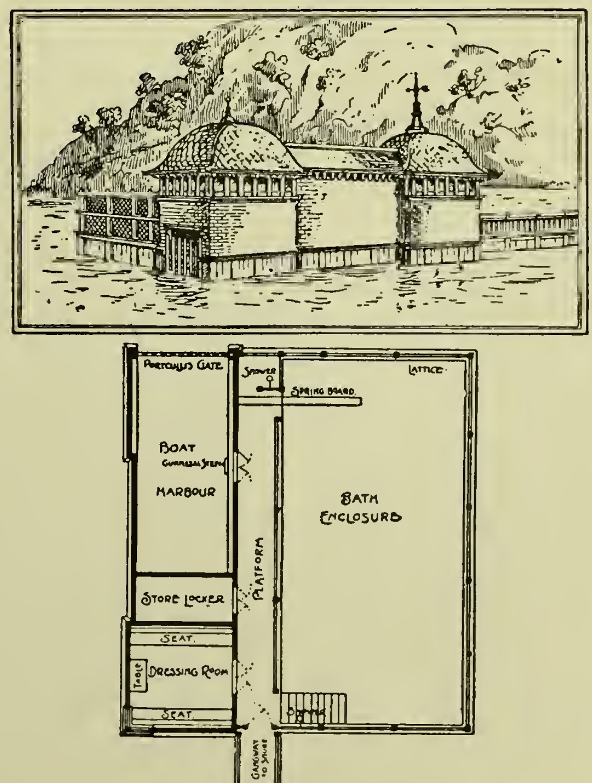


FIG. 205



C. Rosenthal, Architect.

FIG. 206.—Bathing House, Woollahra Point.

often forms part of private home planning, when private land has water frontages, as is common in Sydney, where baths of the character shown in Fig. 206 are often seen.

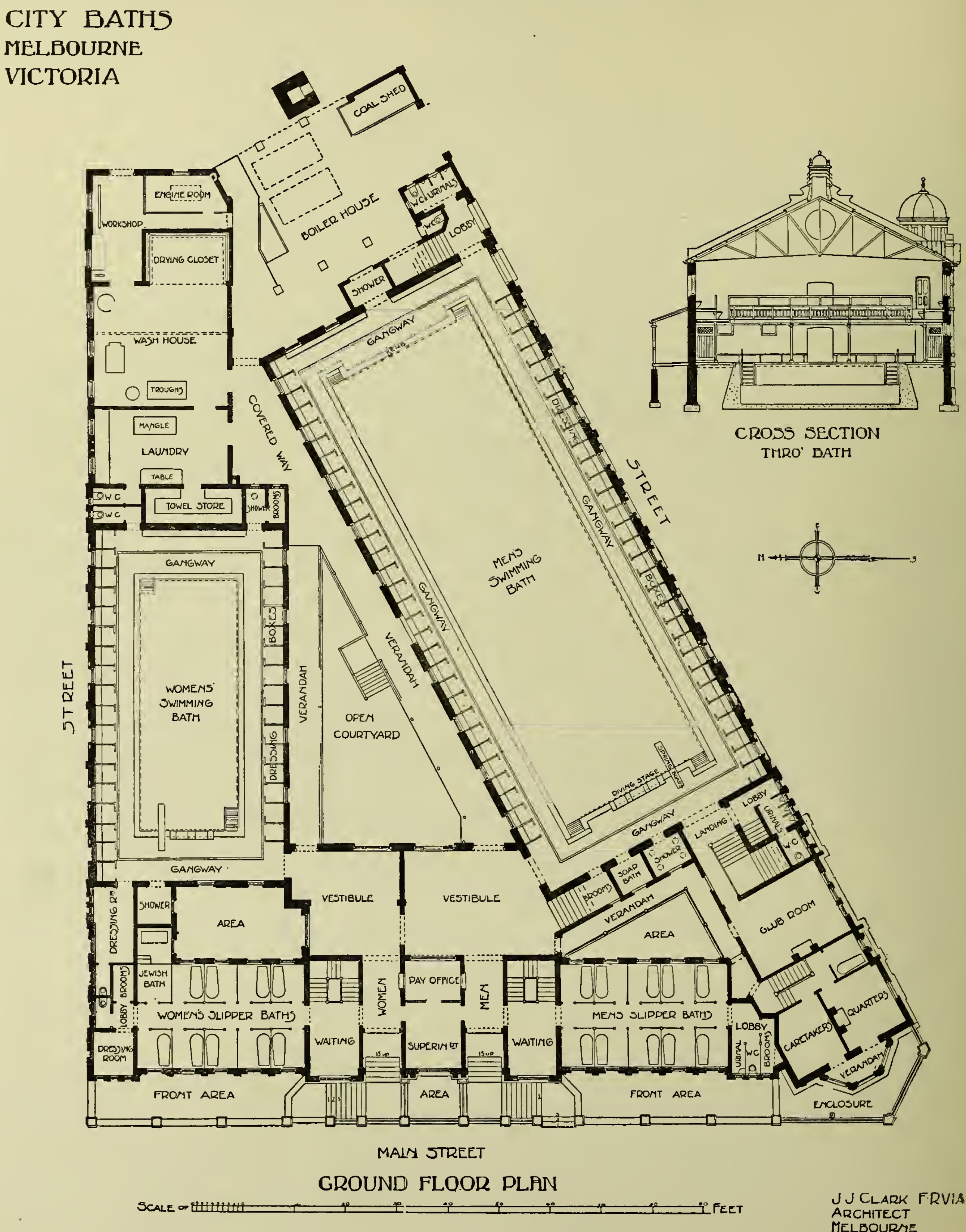


FIG. 207.

The City of Melbourne Baths (Fig. 207) have come, therefore, as a somewhat new department, to supply the requirements of the denser settled portion of the city farthest from the port. Designed by Mr. J. J. Clark, F.R.V.I.A., they occupy a triangular site with a steep fall from back to front, and display some skilful and convenient planning, the £18,000 of cost being well spent. Two large swimming baths are provided,

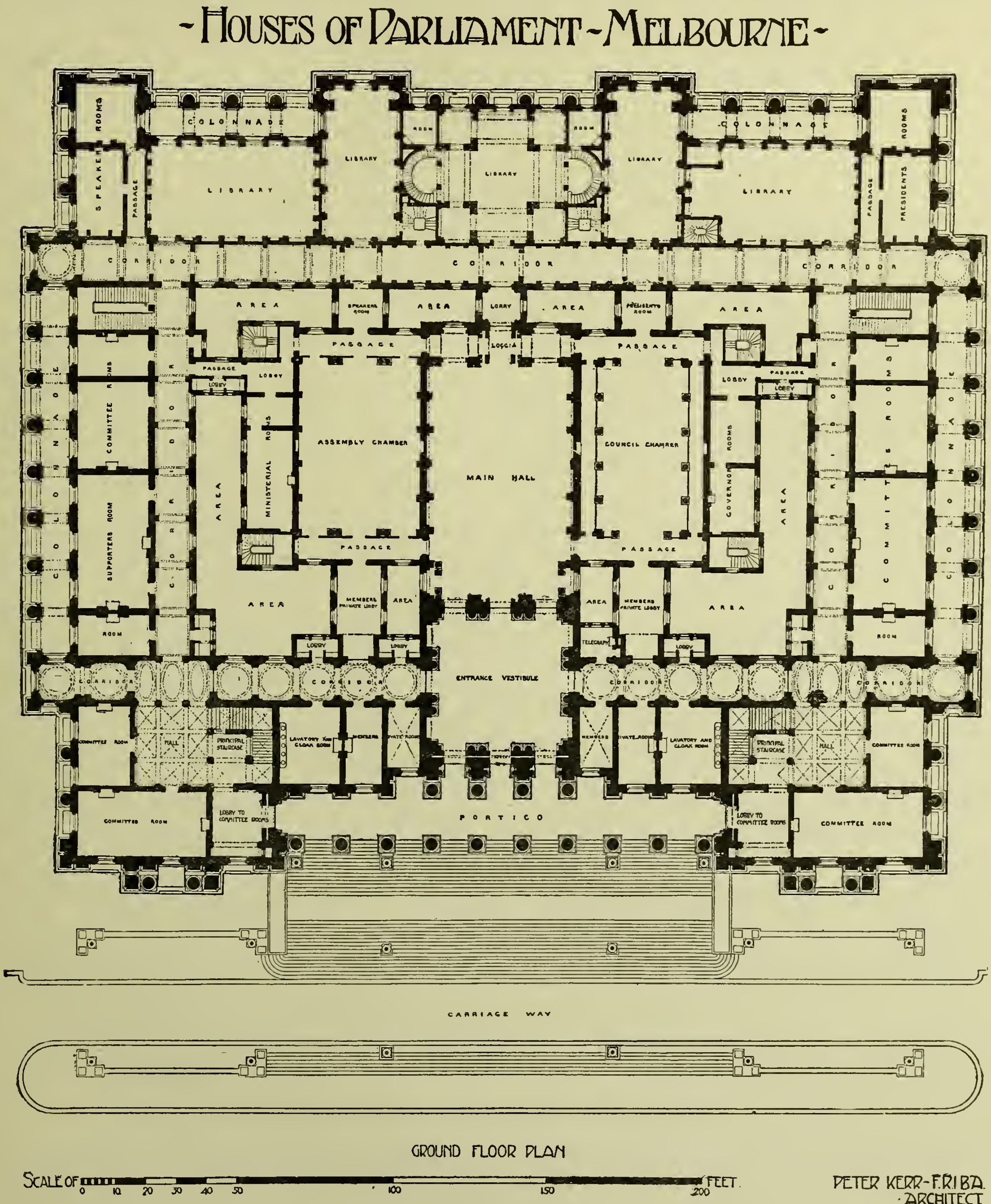


Fig. 208.

besides Turkish, vapour, slipper, and other baths. Very commodious sitting accommodation has been provided in galleries overlooking the men's swimming bath, which is 100 by 32 feet, and closely approaches in size the St. Pancras (London) Bath, which is 100 by 35 feet. The slipper baths are all of American porcelain. Kosher vestibule, out of which a long transverse corridor opens to right and left, while the axis is continued through the main hall, having an assembly chamber on one side and council chamber on the other, and then through a loggia to a second transverse corridor, beyond which the axial passage leads to the main library hall, the

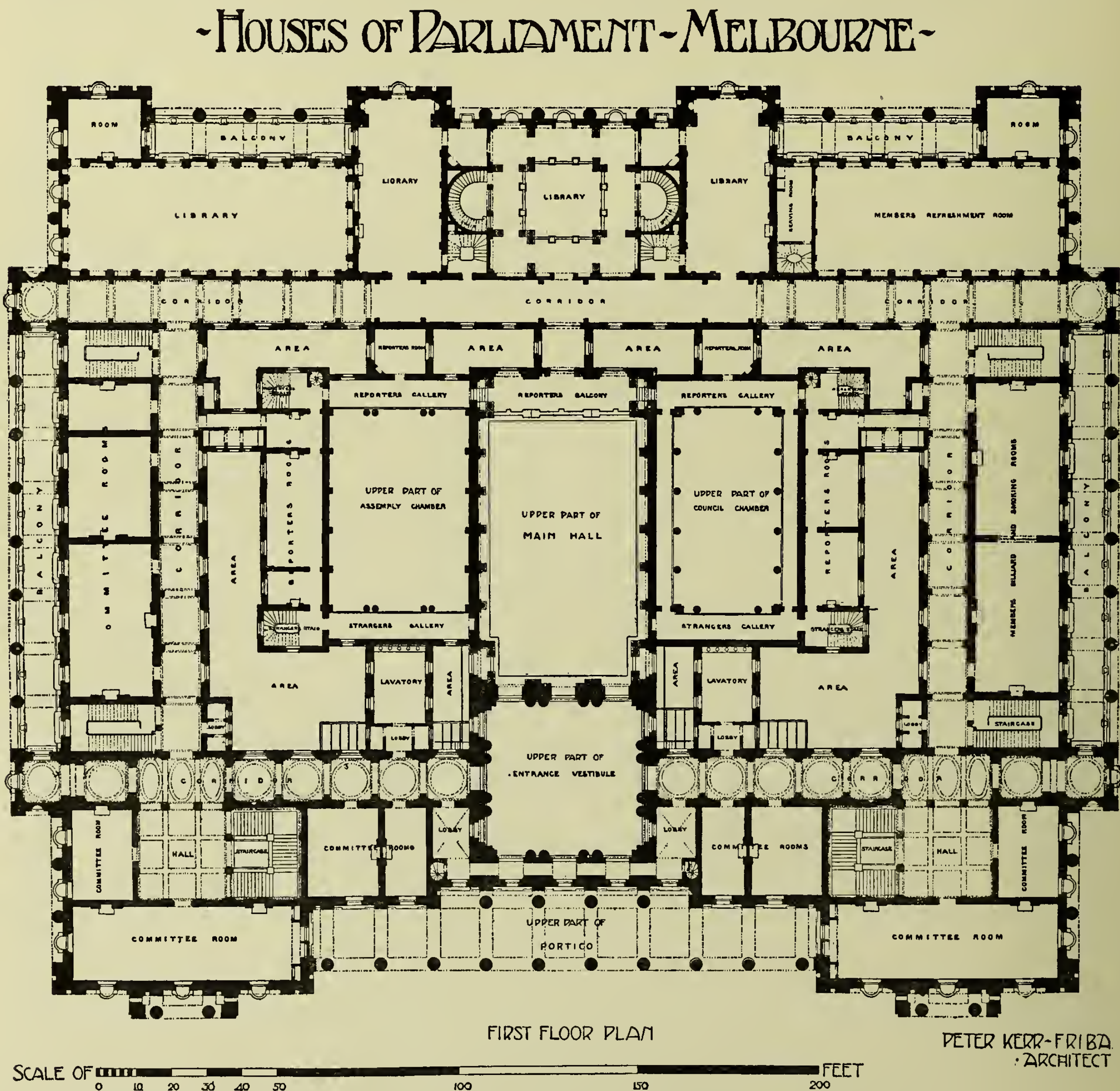


FIG. 209.

baths are provided below for Jewish citizens, and the entrances are so planned as to make for economic administration.

Figs. 208 and 209 illustrate the Melbourne Houses of Parliament now used by the Federal Government. They were designed by Mr. Peter Kerr, F.R.I.B.A., upon simple and noble lines with external porticoes on all sides. There is a main axial entrance to a large various subsidiary libraries being approached from this rear corridor. The front and rear corridors are connected by other longitudinal corridors on either side, lighted by internal areas and giving approach to external committee-rooms underneath the colonnades of the side streets. The principal staircases are not found in the entrance vestibule, but are reached from halls which open at the junction of the front corridor

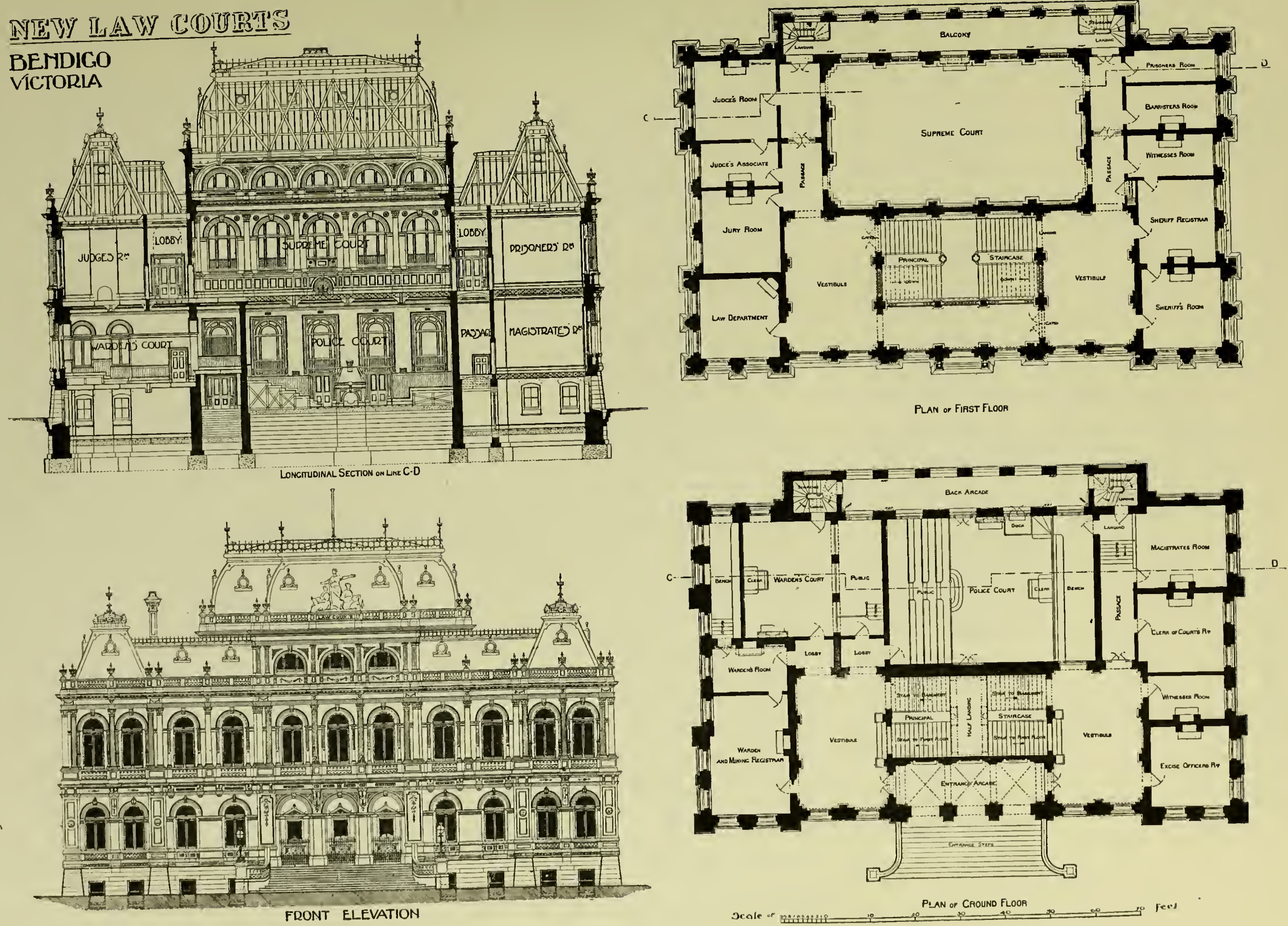
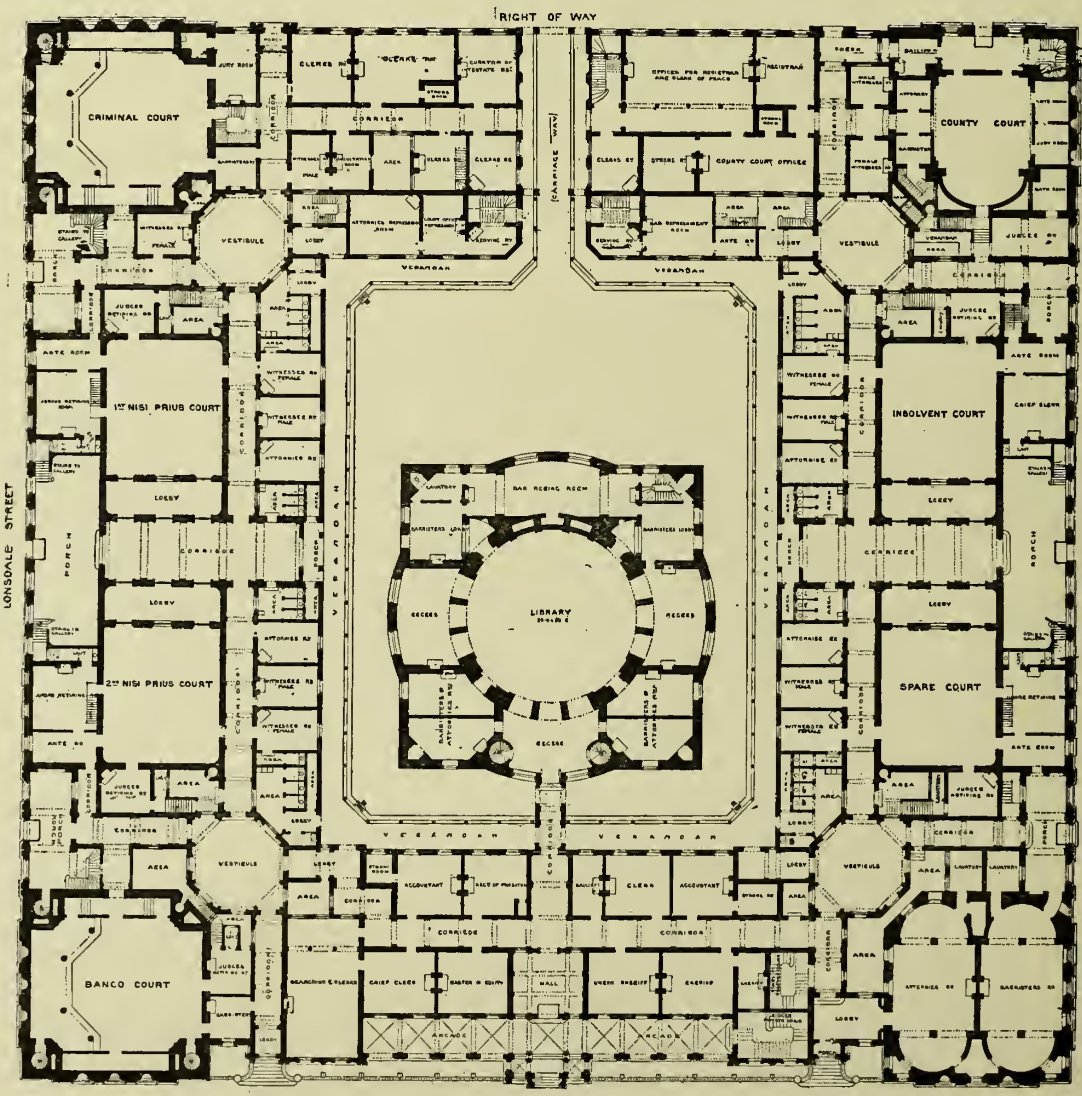

NEW LAW COURTS
BENDIGO
VICTORIA
JUDGES Rm
LOBBY
SUPREME COURT
LOBBY
PRISONERS' Rm
WARDEN'S COURT
POLICE COURT
PASSAGE
MAGISTRATES' Rm
LONGITUDINAL SECTION ON LINE C-D
FRONT ELEVATION
BALCONY
PRISONERS ROOM
JUDGE'S ROOM
SUPREME COURT
BARRISTERS ROOM
JUDGE'S ASSOCIATE
PASSAGE
PASSAGE
WITNESSES ROOM
JURY ROOM
SHERIFF REGISTRAR
PRINCIPAL
STAIRCASE
VESTIBULE
VESTIBULE
LAW DEPARTMENT
SHERIFF'S ROOM
PLAN OF FIRST FLOOR
BACK ARCADE
MAGISTRATES ROOM
WARDEN'S COURT
PUBLIC
POLICE COURT
BENCH
PASSAGE
CLERK OF COURTS Rm
LOBBY
LOBBY
WARDEN'S ROOM
WITNESSES ROOM
HALF LANDING
PRINCIPAL
STAIRCASE
VESTIBULE
VESTIBULE
WARDEN AND MINING REGISTRAR
EXCISE OFFICERS Rm
ENTRANCE ARCADE
ENTRANCE STEPS
PLAN OF GROUND FLOOR
Scale of Feet

FIG. 210.

LAW COURTS. MELBOURNE.

SMITH & JOHNSON.
ARCHITECTS.
MELBOURNE.

WILLIAM STREET ELEVATION.



GROUND FLOOR PLAN.

SCALE OF 0 10 20 30 40 50 100 150 FEET

FIG. 211.

LAW COURTS. MELBOURNE.

SMITH & JOHNSON. ARCHITECTS. MELBOURNE

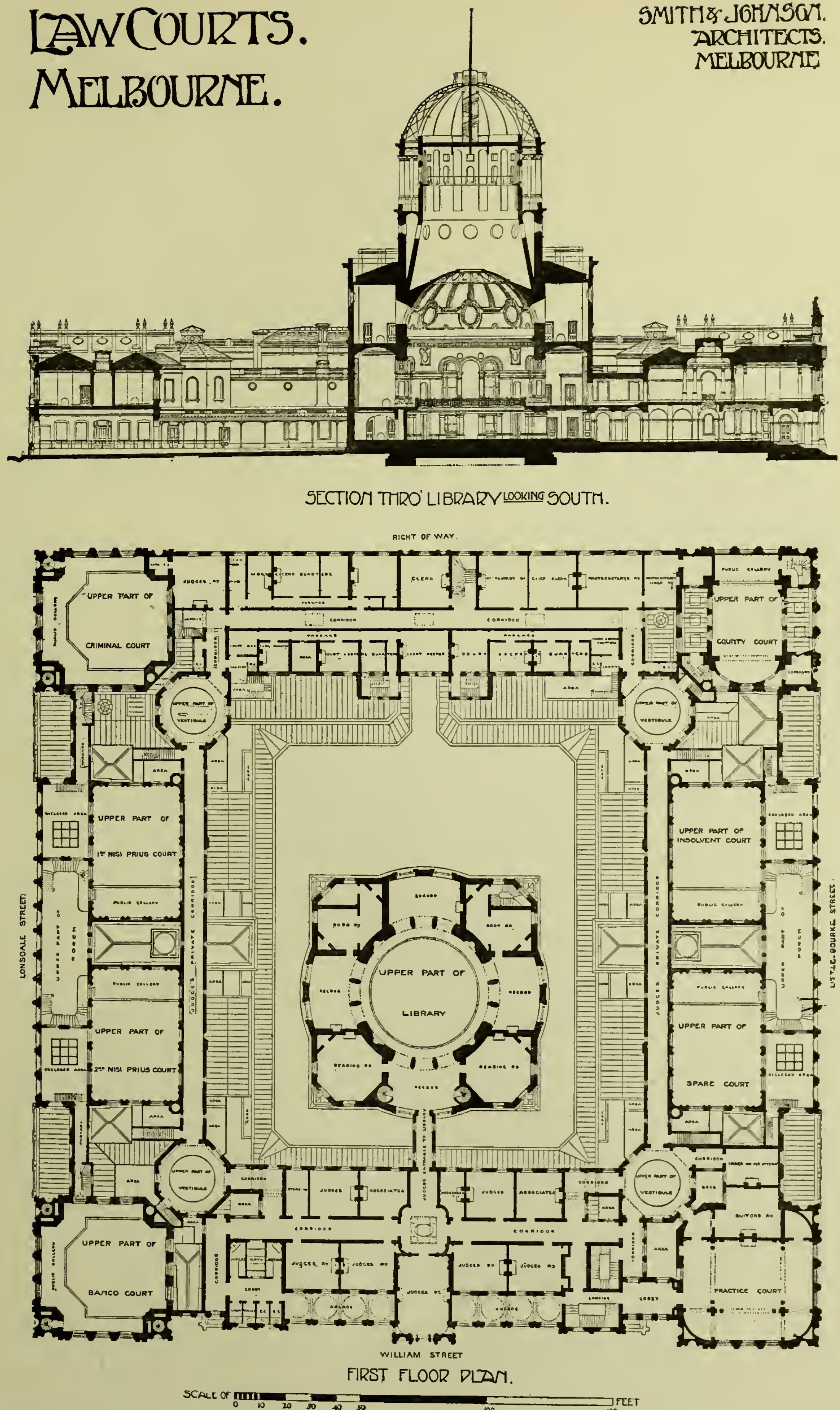
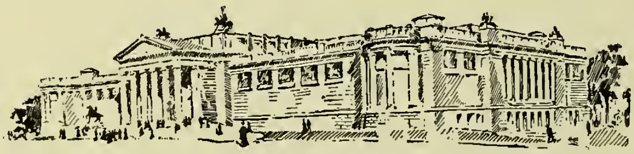
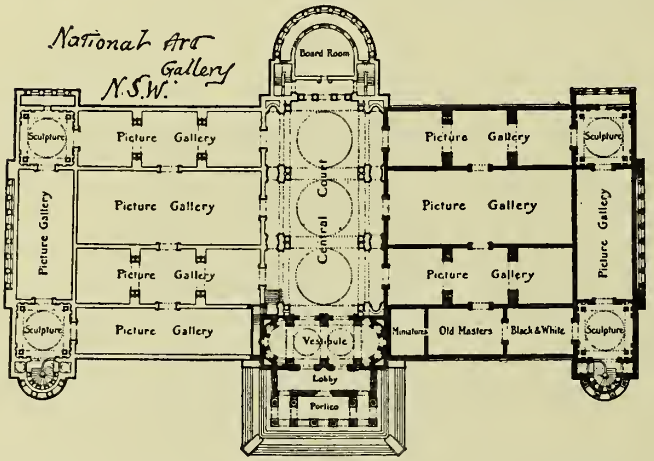


FIG. 212.

with the secondary longitudinal corridors. This corridor arrangement is repeated on the upper floor, where a number of further committee-rooms and libraries are placed, together with the reporters' galleries, the assembly-rooms and council chamber, and a series of refreshment-rooms and billiard-rooms for the members.

The Bendigo Law Courts (Fig. 210), situated in the famous Gold City, is a handsome structure, designed in the Department of Public Works, and cost some £38,000.





Ground Floor Plan. W. L. Vernon Archt

Fig. 213.

The difficulties of its planning were to conveniently combine a series of courts and public offices differing widely in purpose, such as Wardens Courts (where cases dealing with the mining laws are tried), an ordinary Police Court, and the Supreme Courts for Visiting Judges, as well as offices for various permanent officials.

A decidedly bad foundation had to be dealt with, the site being along the line of an old alluvial sludge channel, so that a considerable depth of foundation had to be laid in with specially heavy concreting, the walls being of Harcourt granite up to ground-floor level.

A spacious feature has been made of the principal staircase with the great flanking vestibules, the stairs, handsome wrought brass railings, and heavy gateways making a very impressive composition.

The general inside finish is in Keen's cement worked to very smooth finish, and the joinery work has received careful consideration, the Supreme Court being finished in native black wood and with embossed windows bearing the names of famous colonial judges.

The Law Courts, Melbourne (Figs. 211 and 212), occupy a commanding site in the city, and are bounded on three sides by important thoroughfares, the elevations to Lonsdale and Little Bourke Streets being each 300 feet in length.

The structure was designed in the graceful Italian style, and is executed in white freestone with much fine detail in its construction. A lofty dome carried on a circle of columns rises from the centre of a great labyrinth of courts and corridors to command the city.

The building was carried out by the Department of Public Works, and represents a cost of some £350,000, made up as follows:—

Foundations	£26,890
Superstructure . . .	30,438
Extras	12,000
Dome	75,000
Furniture	20,000

The plan is on the courtyard system, with direct axial entrances from all four frontages, of which the main one is continued to serve a great domed building, used as a library, which occupies a large proportion of the yard. The courts are placed at the corners of the site, where they form pavilions, and others flank the transverse axis, near its entrances from the side streets, while corridors provide communication with the numerous offices. Still, the planning of such edifices has advanced since this was built, as will be seen by comparing these plans with those of the Cardiff Law Courts illustrated in Volume IV., particularly with regard to the sanitary conveniences, and to the careful avoidance of cross traffic between judges, juries, bar, witnesses, and prisoners, and to the means by which the last named are brought into and removed from the courts, while the corridors are not any too well lighted.

The plan in Fig. 213, together with its accompanying sketch, show the scheme, now partly carried out, of the National Art Gallery of New South Wales, for which Mr. W. L. Vernon, F.R.I.B.A., the Government architect, is responsible. The building, which is in Sydney, is erected of warm buff freestone, on a trachyte base, and has an imposing appearance, the Ionic portico, recently added and approached by a flight of trachyte steps and leading to the richly coffered vestibule, being very fine. The lighting has been specially arranged to exclude heat and excess of sun, and good ventilation has been produced by a mechanically driven system of fans.

CHAPTER IV

ECCLESIASTICAL BUILDINGS

(*Contributed by R. J. Haddon, F.R.V.I.A., F.S.A.I.A.*)

St. Mary's Roman Catholic Cathedral, Sydney (Fig. 214), is perhaps the finest specimen of Decorated Gothic architecture in Australia, and has cost up to date some £230,000. It occupies a picturesque and commanding site, and is built of warm yellow brown sandstone, from designs by the late Mr. W. W. Wardell, F.R.I.B.A.

This church has the great internal height of 100 feet, with open timber roofing to nave and transepts, the aisles groined in stone, and the building when completed will be 350 feet in length. There is some very fine stained glass within, and the high altar, of New Zealand Omaru stone richly carved, is an imposing part of the interior treatment.

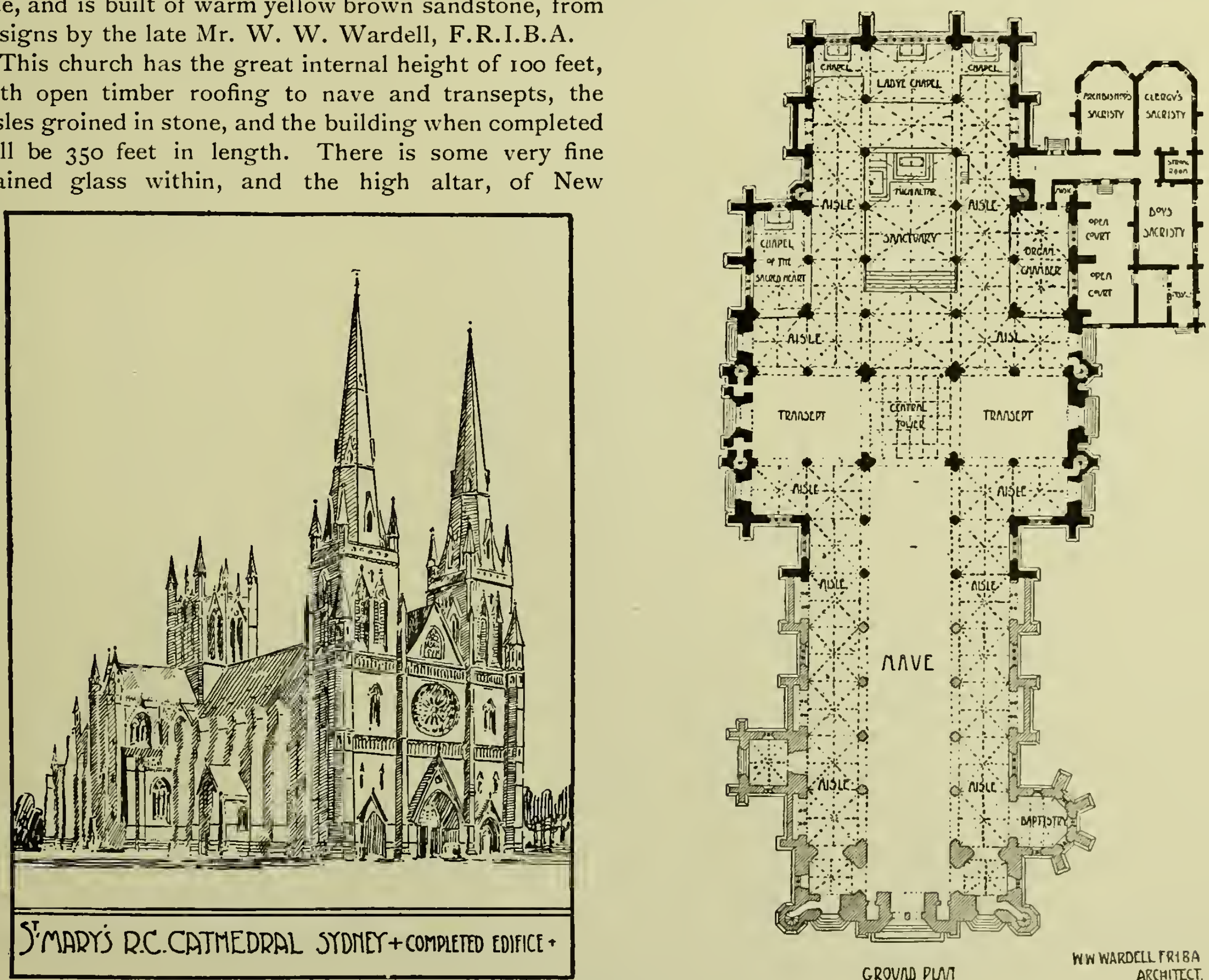
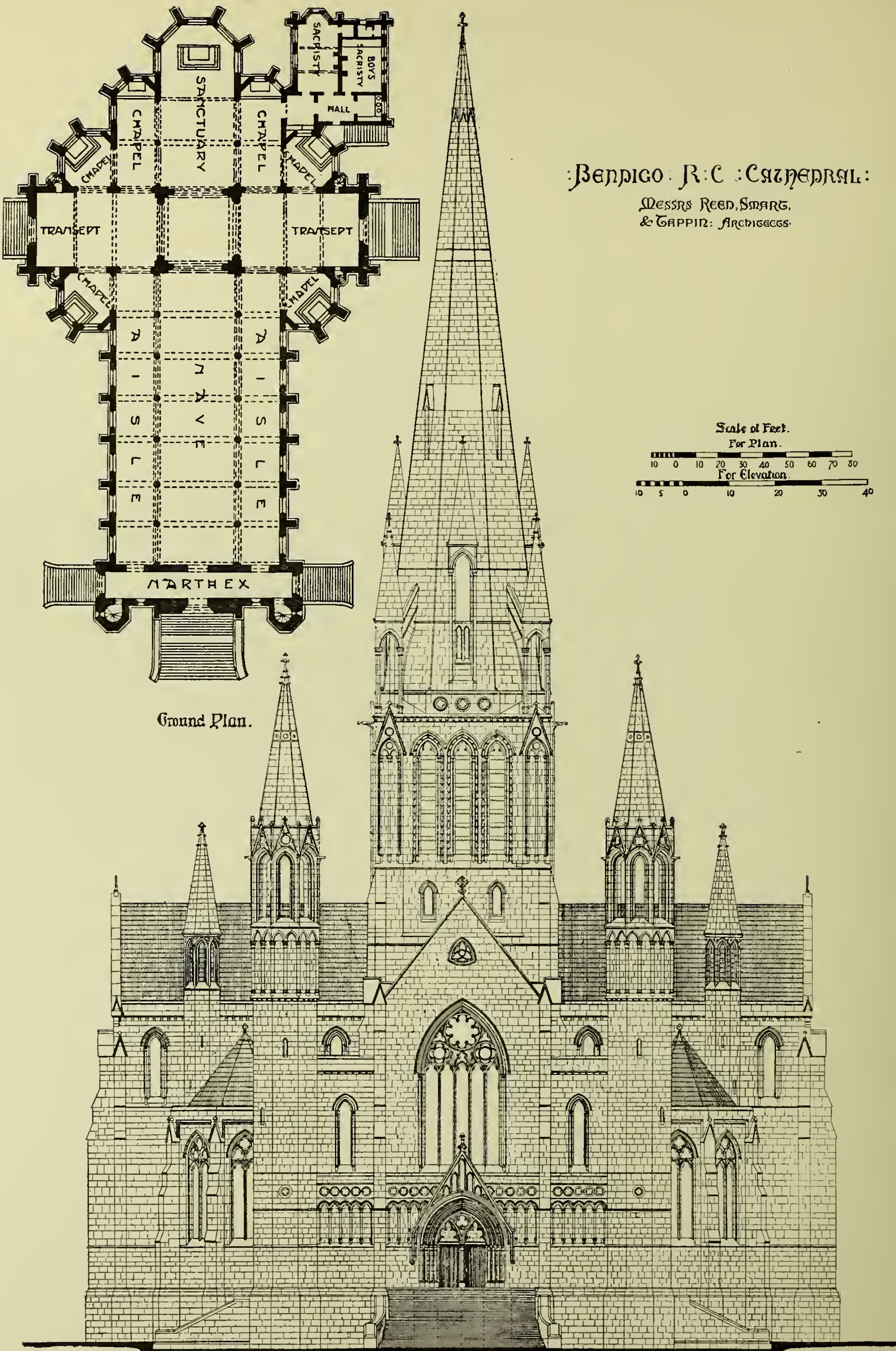


Fig. 214.

In the planning provision is made for the numerous chapels and altars necessary for the full Roman Catholic ritual, while a separate but adjoining building is provided for the various sacristies.

The Cathedral Church at Bendigo, Victoria (Fig. 215), designed by Messrs. Reid, Smart, & Tappin, architects, is upon a cruciform plan, with four transept chapels, besides one on either side of the chancel formed by the eastward extension of the side aisles. The nave is divided into bays, having a centre to centre measurement of 17 feet 6 inches, the over-all measurement of the structure being nearly 300 feet. The width of the nave is 35 feet, with 17 feet 6 inches side aisles; the transepts are 35 feet wide, the octagonal chapels being 26 feet across. The height of the main walls is 60 feet, the nave arcade being 30 feet high. The roof is con-



Ground Plan.

:Bendigo: R:C :Cathedral:

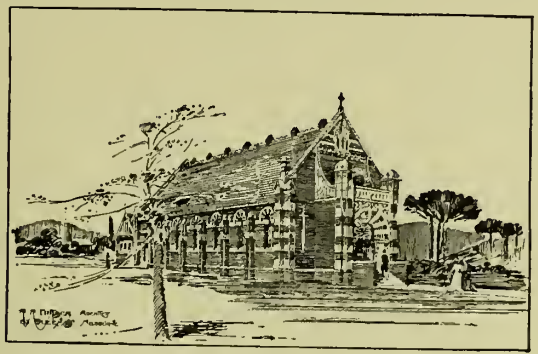
Messrs Reed, Smart, & Tappin: Architects.

Scale of Feet.
For Plan.
10 0 10 20 30 40 50 60 70 80
For Elevation.
10 5 0 10 20 30 40

Front Elevation

FIG. 215.

structed of open timbering throughout on the hammer-beam principle with angel carvings.



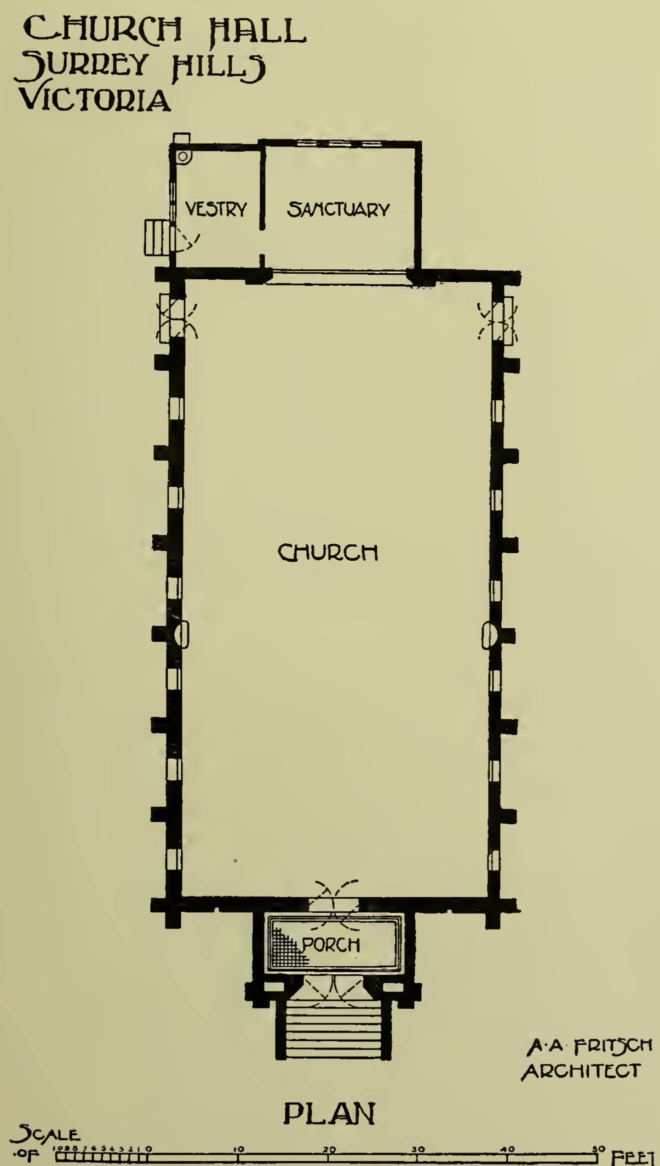


FIG. 216.

There are dual organ chambers in the western gallery, where accommodation is also planned for the choir.

The building is of Barabool Hill freestone, which is of greenish-brown colour, with dressings of Wawin Ponds stone, buff in colour, these stones being quarried in the State of Victoria.

The style is Early Decorated, and makes an effective architectural composition in the city. The two western towers, with plain stems working up into Decorated belfries and spirettes, give dignity and cathedral character to the front, an effect greatly heightened by the large flight of steps leading to the western doors, supplemented by arcaded band work which flanks the doors and extends right up to towers on either side.

The height of the western window is 38 feet. It is filled in with a handsome stained-glass window executed by Hardmann at a cost of £1000. The high base of the building and the steps have been carried out in Victorian granite.

The cost to date has been about £40,000, and it is

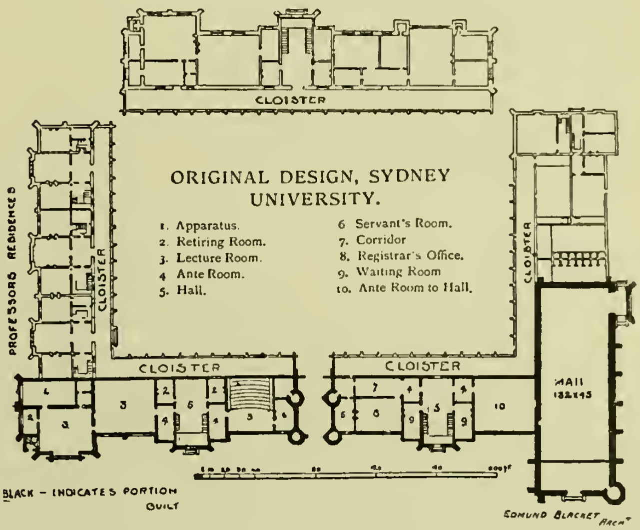


FIG. 217.

estimated that when completed the total cost will be about £70,000.

Fig. 216 shows a Roman Catholic church of ease erected upon a commanding site at Surrey Hills, a few miles from Melbourne.

The church proper is rectangular in shape, with a half-open timber roof having trusses resting upon the buttresses shown. The main entry is through a bold semicircular arched doorway, which gives pleasing dark shadows in the sunny days, the effect being heightened by a well-designed wrought-iron scroll work grille with a gilded cross in the centre, which, having the back shadow setting, can be seen from a great distance. The walls are of red bricks, the roof covering being of American slates. The vestry and sanctuary are treated in a semi-domestic style with half timbering. The architect is Mr. A. A. Fritsch, F.R.V.I.A., of Melbourne.

The design of the main portion of the Sydney University buildings, which are perhaps more rightly

included in this chapter than under the heading of schools, is shown in Fig. 217, the work having been carried out by the late Edmund Blacket, architect. They occupy a magnificent site, and in general treatment are very satisfying to the critical sense. The interior of the great hall is perhaps the most interesting part of the building, with its fine cedar hammer beam roof, mellow stonework, and well-designed stained glass. Other buildings have been added within the university reserve that are too heterogeneous to be altogether satisfactory as architectural compositions.

The plan is arranged on the quadrangle system adopted at the old colleges of Oxford and Cambridge,

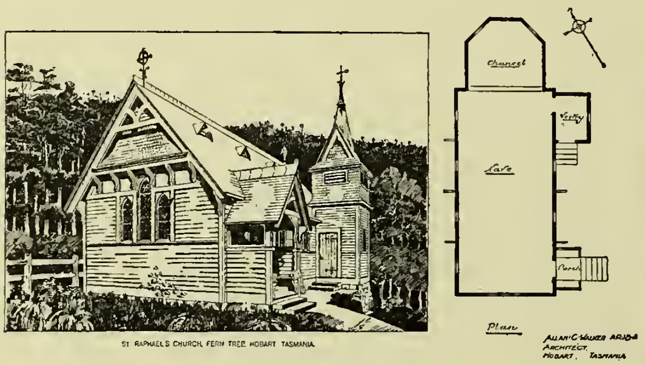


FIG. 218.

but with cloisters round the garth, from which the various lecture-rooms and apartments are reached.

St. Raphael's (Church of England) at Fern Tree (Fig. 218), under the shadow of Mount Wellington, is a picturesque design by Mr. Allan C. Walker, A.R.I.B.A., carried out in locally grown timber. There is a stone foundation; the walls are of hard-wood studding covered with hard-wood weather-boards. The roof and upper portion of tower and gable are covered with split gum shingles. The inside is lined throughout with 3-inch V-jointed hard-wood boarding. The weather-boards are painted a brick red, and the shingles have assumed a silvery grey colour, the whole harmonising with the surrounding evergreen foliage.

The drawing given in Fig. 219 may be taken as a type of the small Nonconformist church required in Australian country towns. This Methodist church has

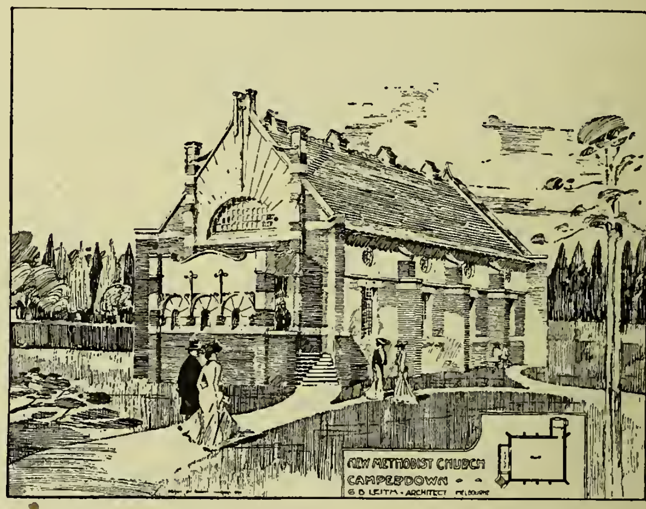


FIG. 219.

recently been erected at Camperdown, the architect being Mr. G. B. Leith. It shows a compact brick building following the rectangular plan, with an angular flight of steps up to a long porch, so arranged as to keep out wind and dust. The walls are of red bricks with top finishings of buff coloured rough-cast. There is an open timber roof with Kauri lining. The work as a whole makes a pleasing and original composition.

CHAPTER V

MISCELLANEOUS BUILDINGS

(*Contributed by R. J. Haddon, F.R.V.I.A., F.S.A.I.A.*)

The New Opera House, Melbourne, designed by the Hon. William Pitt, F.R.V.I.A., and shown in Fig. 220, is one of the most up-to-date theatres in Australia. The new building occupies the site of one of Melbourne's earliest play-houses, which was condemned by the Public Health Department as unsafe in 1900. The theatre occupies a site 66 feet wide by 300 feet deep, and consists of stalls, dress-circle, and gallery, with total seating accommodation for 1800. All entrances are situated in the main street, with escapes at side of building leading to small street at rear. The entrances to stalls from main street lead to a spacious crush-room with all necessary cloak-rooms, etc., attached ; from this crush-room two fine marble staircases lead to a spacious lounge adjoining entrance to dress circle, with a fine saloon bar and cloak-rooms off same. The gallery has two entrances from main street. The auditorium has a fine appearance, being roomy and well proportioned. The whole of the architectural treatment has been carried out in Mooresque, which has given the decorative artist full scope for colour, which has been well taken advantage of. The saucer or dome above has been provided with a sliding roof, which gives an unimpeded exit for the heated atmosphere of the theatre, and has proved the greatest boon that theatre-goers have been provided with of late years. It can be said that there is not one bad seat in any portion of the auditorium. The pitch of galleries and stall floors strikes a visitor from other parts of the world as something new ; this is the outcome of a complete study of sighting, and adds considerably to the comfort of theatre patrons. The proscenium opening has been provided with a double asbestos fireproof curtain, which is lowered at every performance between acts to ensure proper working if actually required. The stage has a depth of 50 feet by a width of 63 feet, and a height of 60 feet to gridiron floor above ; the whole of which is clear working space, enabling large productions to be staged. Two large scene docks are provided, one at back and the other at side of stage ; also necessary property-rooms, and a large paint-room with two frames. There is a four-storeyed block of dressing-rooms, with all necessary wardrobes and sewing-rooms attached. These dressing-rooms have only one entrance on to stage, with fireproof doors, thereby lessening the risk in case of fire.

The large warehouses illustrated in Fig. 221 have an important stone and brick frontage design to one of the principal streets of Melbourne, treated in the Renaissance manner, and have substantially constructed back buildings. The special requirements of the City Building Act have influenced the planning, and required certain subdivision of the spaces. The ground-floor front is planned for the various offices, sample-rooms, etc., and has elaborate wood fittings, the general office occupying the whole of the frontage to main street on the first floor.

The warehouses have three great divisions, each served with goods lifts from the side street, which give free access for working. There are five floors in the warehouses, each designed for heavy weight bearing, with steel columns, uprights, etc. A basement extends under the front portion, which has a considerable fall westward. The architect is Mr. D. C. Askew, C.E., F.R.V.I.A.

One of the staple industries of Australia, and a largely increasing one, is that of the export of frozen meat. In Queensland and New South Wales the treatment of cattle and sheep has assumed large proportions ; while in Victoria the trade is more confined to the export of lambs and sheep, and it is anticipated that with closer settlement and smaller holdings this will be greatly increased. In the northern States of Australia the freezing works are capable of handling large numbers of cattle, and include the treatment of all the bye-products, such as oleo, glue, meat extracts, and artificial blood manures. We give in Fig. 222 a plan of the Imperial Freezing Works, the property of Messrs. W. Anglis & Co., of Footscray, Victoria, which are also arranged as abattoirs for killing and chilling cattle for local consumption. The plan shows the arrangements for yarding cattle and sheep, which are killed on the ground floor (A), hung in well-ventilated rooms (B) to cool, and then transferred on overhead rails to the chilling rooms (C) for delivery to the various butchers' shops belonging to the company. The cattle are killed in crush pens, and hoisted on to the overhead rails for dressing. The sheep are passed along races to the killing pens, and also hung on similar rails. There are also scalding tanks (D) for the treatment of hogs. The sheep and lambs for export walk up

inclined roadways (E) to the first-floor killing pens (F), and after being dressed hang in a large louvred building (G) to remove the animal heat; from thence delivery into insulated trucks on siding, by which they are conveyed to the wharf for export. The offal passes through pipes to the lower floor, and, together with

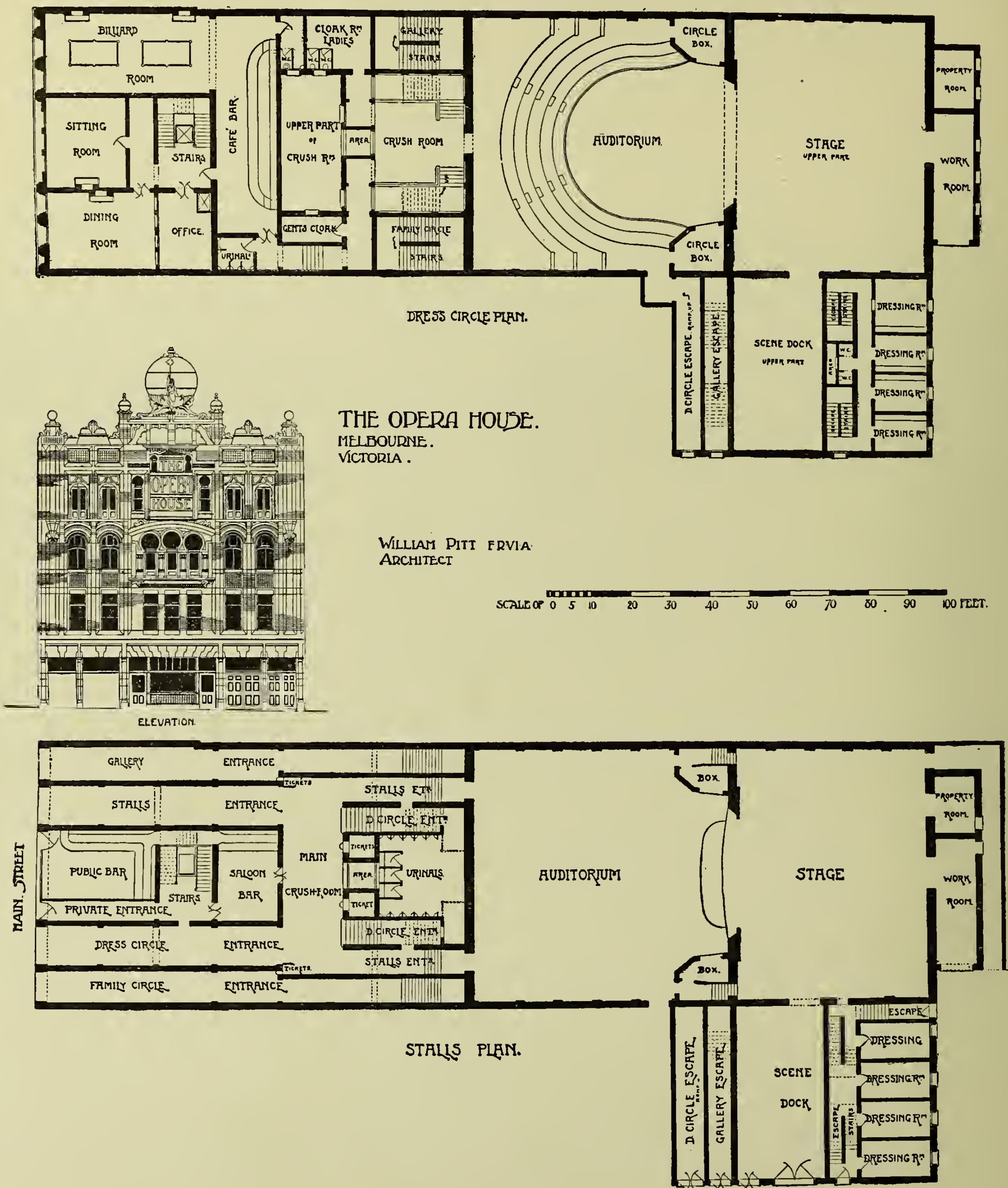


FIG. 220.

they pass by a system of rails and switches into the freezing chambers (H). After being frozen they are bagged and lowered into the stores (J), ready for the refuse from the treatment of local produce, is conveyed by a tramway (K) to the boiling-down works for the production of tallow, the residue being

dessicated in a revolving drier (L) to form blood manure. The pelts are dried and baled for export, or sold locally to pelmongery establishments.

The freezing and chilling plant consists of two large machines driven by compound engines, and the cold air is distributed through the various freezing chambers and stores by air ducts, the cold air being driven through by means of fans actuated by electric motors. The whole of the works are lighted by electricity, and this power is also used for the various pumps, twists, etc. These works are capable of freezing about 3000 lambs per day, and storing about 40,000, and are considered to be the most complete of their size in existence. Owing to their being built near a centre of population they are of a most substantial character, every precaution has been taken to remove any objectional odours from treatment, and they are perfectly sewered and supplied with water.

The works, which cost about £50,000, have been carried out from plans and under the supervision of Mr. Charles D'Ebro, Assoc.M.Inst.C.E. of Melbourne, an Australian expert in freezing works design.

Narada (Fig. 223) is a typical old sheep station in the western district of Victoria, at the foot of the Anakie Ranges, which has been recently remodelled by Messrs. Laird & Barlow, architects.

The old walls were of cobble stone masonry, and have been renewed with bluestone quarried near the house, the planning being generally brought up to modern requirements, including liberal verandah space. There are offices, too, for bookkeeper and men; but the planning of the old building is elementary, with a dark central passage on each floor.

The water supply is by gravitation from the ranges, with storage in tower over lounge. The dairy has double walls and roof, and is partly under ground. There is a septic tank system of sewerage, the effluent being used in irrigation for the growing of lucerne.

The homestead at Mulwala, on the Murray River, N.S.W. (Fig. 224), has been built for a sheep squatter in the hot district of N.S. Wales, where the summer temperature averages 116° in the shade, the architect being Mr. W. M. Shields.

The Australian preference for a one-storeyed building is here well illustrated, and the planning is characterised by a 9 feet verandah all round the main apartments, from which they are reached rather than by means of internal corridors; while passages for cross ventilation are specially arranged. All doors and windows are fitted with fly and insect-proof wire-netting, and the walls are all built hollow, of bricks manufactured on the site. The timbers are of native red gum, with flooring of Murray pine. These woods are used as white ants are a pest in this district, being proof against them.

The roof is covered with heavy gauge galvanised corrugated iron, for the purpose of obtaining a supply of drinking water, the ceilings being covered with insulating material.

Another example of an Australian homestead is Tocumwal (Fig. 225), designed by Mr. Arthur Peck, F.R.V.I.A. In this case the central passage, so much used in the older Australian houses, is carried

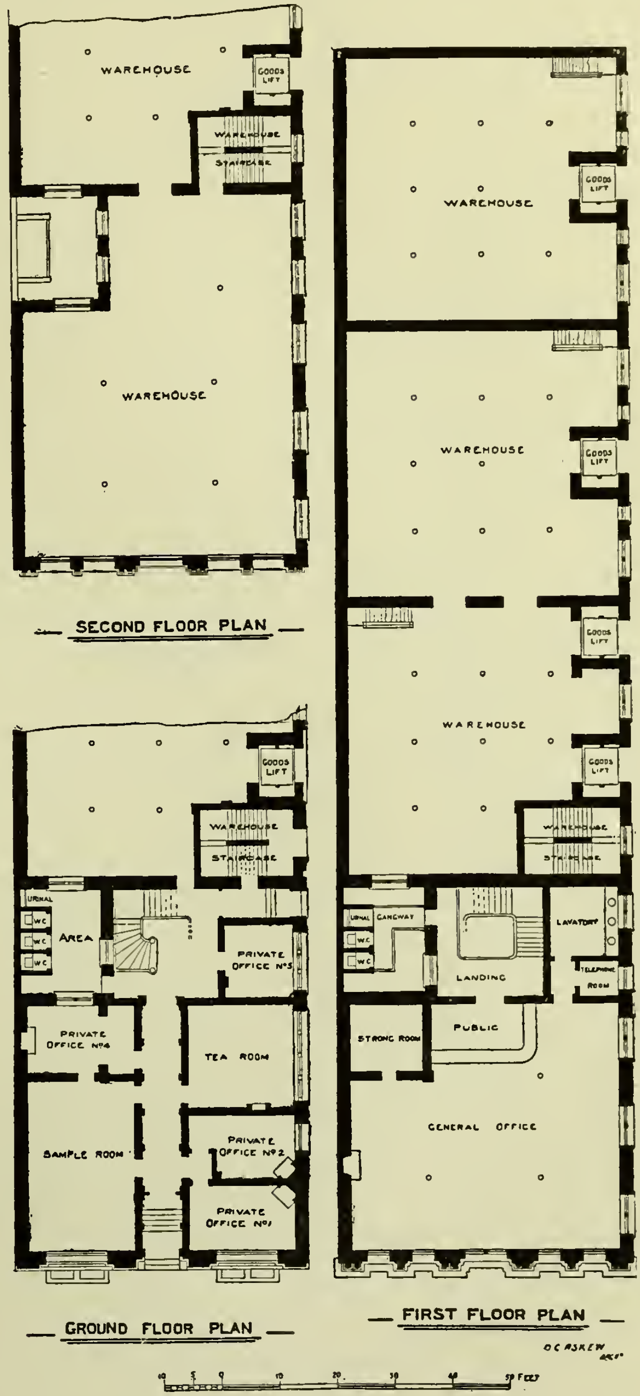


FIG. 221.

right through, and so can be utilised for ventilation. The verandah is carried right round the house, and a covered way leads from it to a separate block containing the laundry and detached w.c.'s, the approach being so placed as to be screened from view from almost the whole of the verandah. The kitchen is at the extremity

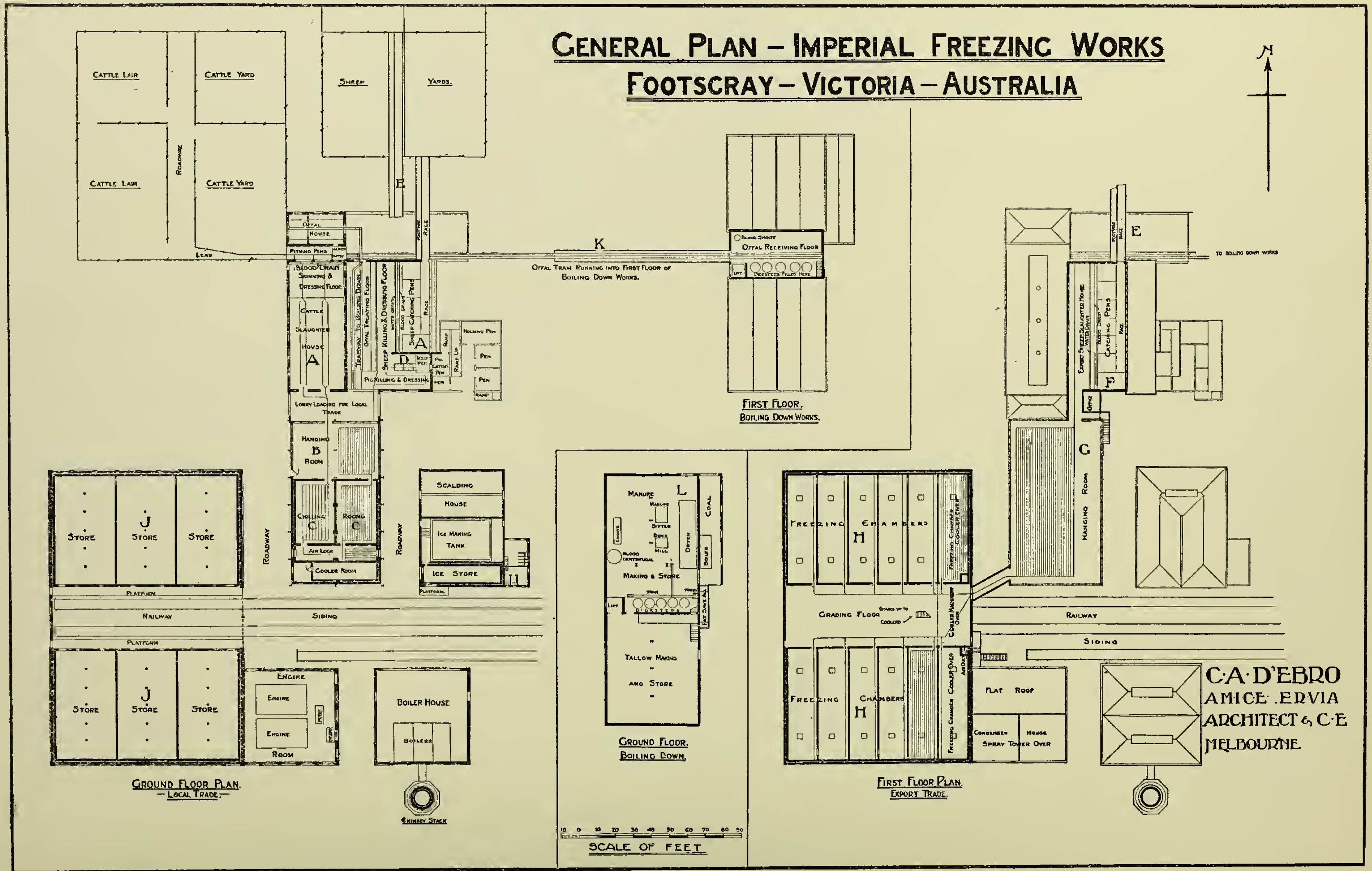

GENERAL PLAN – IMPERIAL FREEZING WORKS
FOOTSCRAY – VICTORIA – AUSTRALIA
N
CATTLE LAIR
CATTLE YARD
CATTLE LAIR
CATTLE YARD
ROADWAY
LEAD
SHEEP
YARDS.
E
FOOTWAY
RACE
OFFAL HOUSE
PITHING PENS
BLOOD DRAIN SKINNING & DRESSING FLOOR
CATTLE SLAUGHTER HOUSE
A
TRAMWAY TO BOILING DOWN
OFFAL TREATING FLOOR
SHEEP KILLING & DRESSING FLOOR
BLOOD DRAIN
SHEEP CATCHING PENS
RACE
A
D
PIG KILLING & DRESSING
HOLDING PEN
PEN
PEN
RAMP
RAMP UP
LORRY LOADING FOR LOCAL TRADE
HANGING B ROOM
COOLING C
ROOMS C
AIR LOCK
COOLER ROOM
ROADWAY
SCALDING HOUSE
ICE MAKING TANK
ICE STORE
PLATFORM
K
OFFAL TRAM RUNNING INTO FIRST FLOOR OF BOILING DOWN WORKS.
BLOOD SHOOT
OFFAL RECEIVING FLOOR
LIFT
DIGESTERS FILLED HERE
FIRST FLOOR. BOILING DOWN WORKS.
TO BOILING DOWN WORKS
E
EXPORT SHEEP SLAUGHTER HOUSE
CATCHING PENS
RACE
F
OFFICE
G
HANGING ROOM
STORE
J
STORE
STORE
PLATFORM
RAILWAY
SIDING
PLATFORM
STORE
J
STORE
STORE
ENGINE
ENGINE
ENGINE
ROOM
BOILER HOUSE
BOILERS
CHIMNEY STACK
GROUND FLOOR PLAN. – LOCAL TRADE. –
MANURE
L
COAL
DRYER
BOILER
MILL
BLOOD CENTRIFUGAL
MAKING & STORE
LIFT
DIGESTERS
FAT SAVE ALL
TALLOW MAKING AND STORE
GROUND FLOOR, BOILING DOWN.
SCALE OF FEET
FREEZING CHAMBERS
H
FREEZING CHAMBER COOLER OVER
GRADING FLOOR
STAIRS UP TO COOLERS
COOLER MACHINERY OVER
FREEZING CHAMBERS
H
FREEZING CHAMBER COOLER OVER
AIR DUCT
FLAT ROOF
CONDENSER HOUSE
SPRAY TOWER OVER
FIRST FLOOR PLAN. EXPORT TRADE.
RAILWAY
SIDING
C·A·D'EBRO
AMICE. ERVIA
ARCHITECT & C·E
MELBOURNE

FIG. 222.

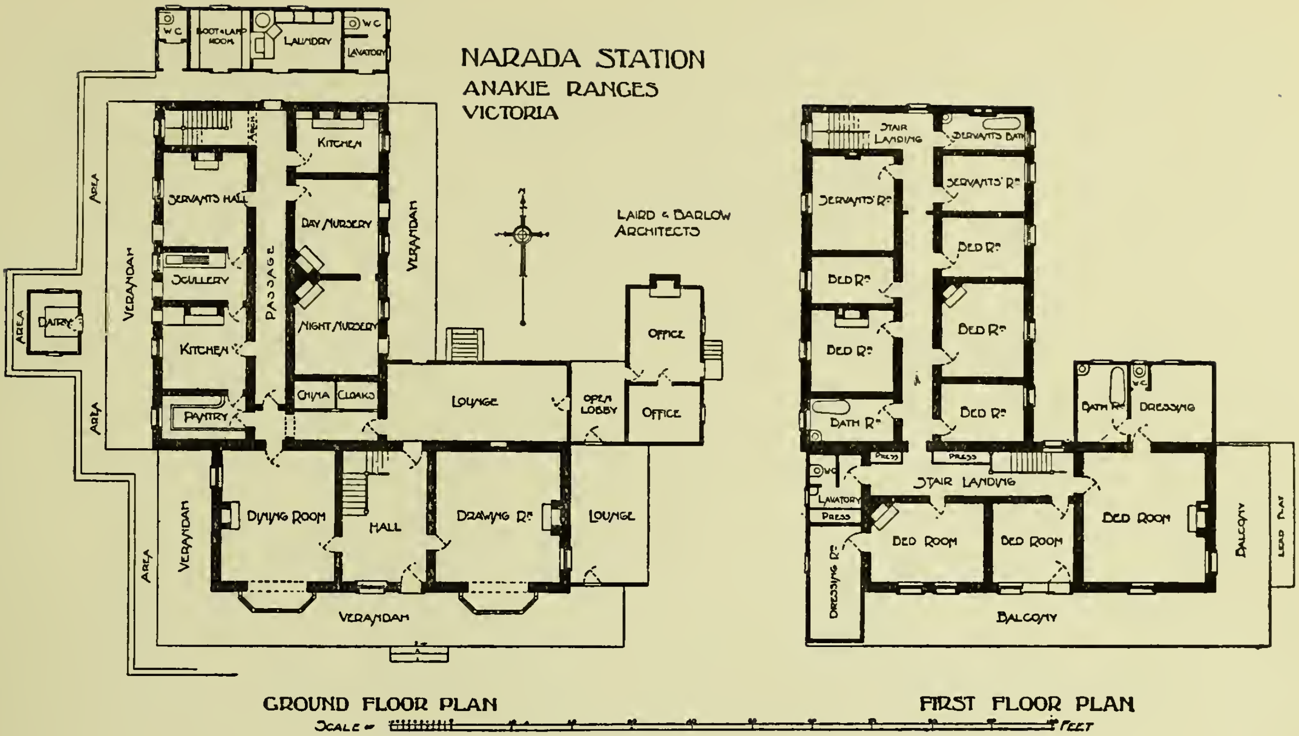


FIG. 223.

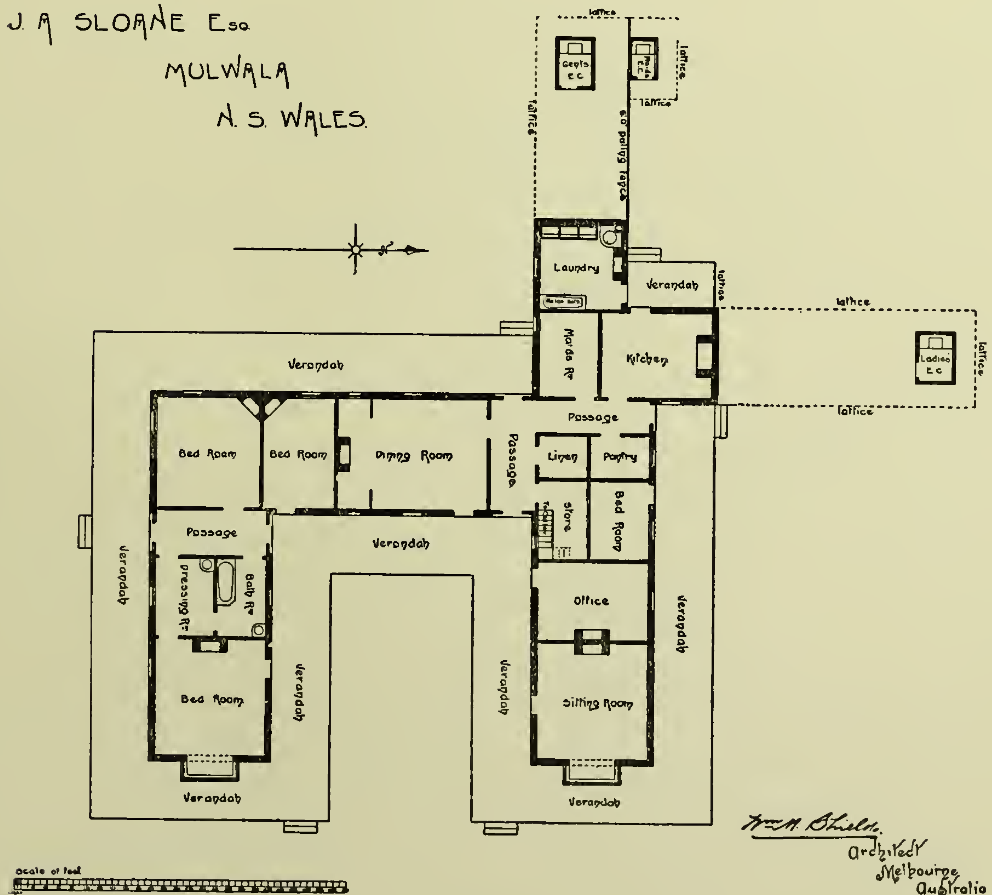


FIG. 224.

of an extended wing, and can easily be disconnected by cross ventilation if desired.

The plan shown in Fig. 226 is for stabling accommodation for a country doctor's horses in a hot district of Australia. The various apartments are arranged conveniently under cover and all under one general roof, the portion over stalls and loose-box being two

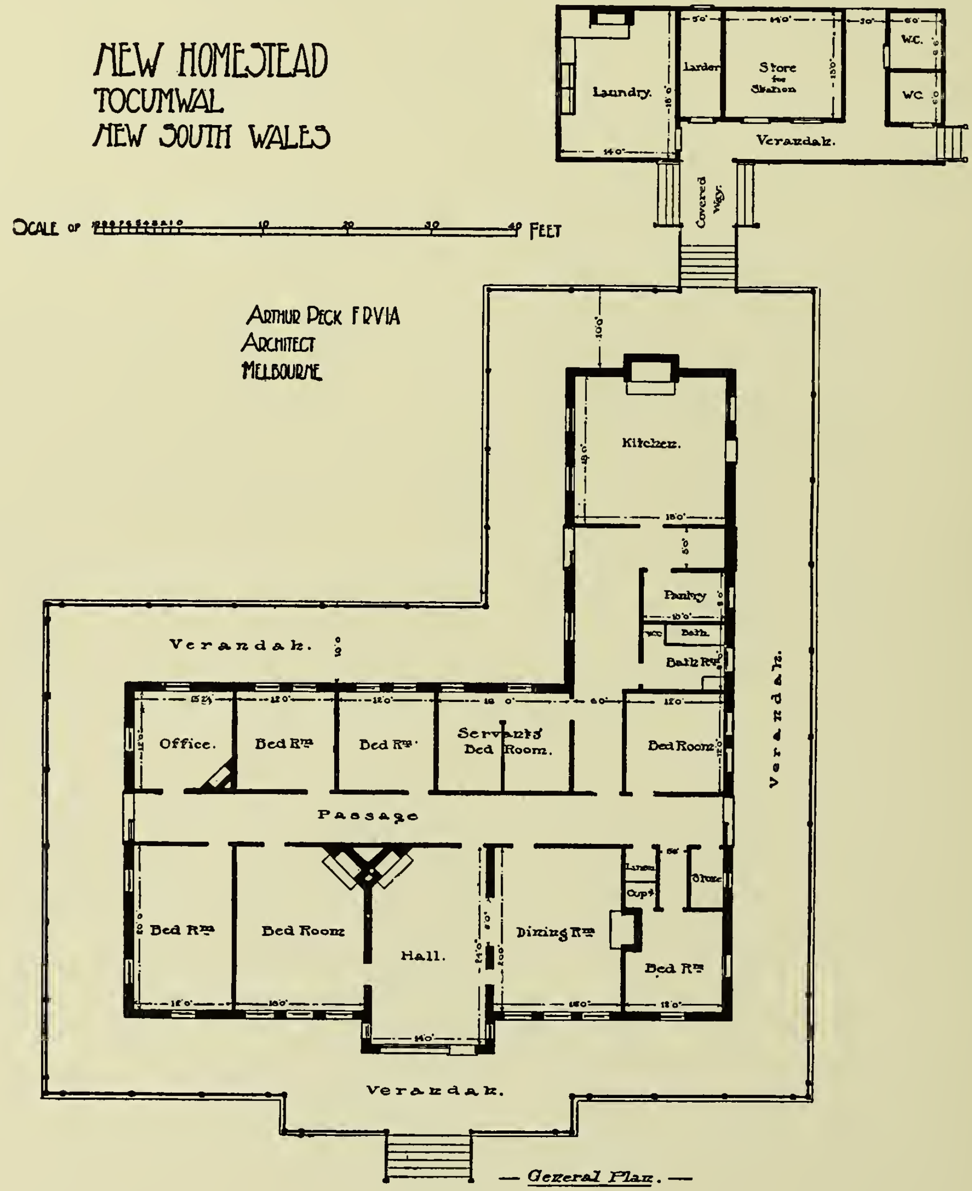


FIG. 225.

storey, for the double purpose of loft accommodation and keeping stalls, etc., cool. There is little difference, it will be noticed, between this and an English stable of similar size.

The coach-house roof is protected by insulating material, and the washing area in front of same is so arranged as to protect vehicles from the direct rays of the hot sun when being washed, a provision much needed to prevent destruction of paint and varnish.

Instead of ordinary feed racks at the head of stalls supplied from above, a well is provided in loft floor for the purpose of lowering hay and bedding to stalls, etc., below.

Instead of chaff being bagged, as is usual, a chaff-in-bulk room is provided. By this means the chaff is kept absolutely free from mice and other vermin. The supply is passed through an outside trap door and staging direct from carts, and slot boards are provided in place of the ordinary inside door. An outside door is provided to loose-box, giving access to sand bath.

In this wood-frame building the walls are entirely constructed of locally grown hard wood, with outside covering of imported red deal weather-boards. All posts, bottom rails, plates, stumps, etc., near or in ground are of picked red gum, twice coated with boiling

tar. The internal partitions, etc., are of picked hand-dressed local hard wood, and the general pavings of Melbourne bricks.

Mr. W. M. Shields, F.R.V.I.A., is the architect.

Fig. 227 is a plan of stabling for an Australian sheep station homestead, and shows generous accommodation for various kinds of horses and vehicles. The buildings form part of the homestead block, which comprises also shearing sheds and other necessary buildings for the work and the workmen engaged upon the place.

A Dairy and Butter Factory may be defined as a building for the receipt and storage of milk and cream, and its manufacture into butter or some other marketable product. Some years ago the Victorian Government offered a bonus for the manufacture and export of butter, which the invention of the separator and the establishment of freezing chambers for oversea carriage rendered both possible and profitable ; and since that date the industry, advancing by leaps and bounds, has grown to enormous proportions, so that to-day the butter factory, with its outlying creameries dotted around it, like satellites about a planet, is a necessary adjunct in every country centre.

A general knowledge of the proper handling of milk and cream, their treatment, and the various processes to which they are subjected in their manufacture into butter or cheese, together with an intimate acquaintance with the mechanical units which constitute the plant and the proper placing and housing of same, are a necessary equipment for the architect who desires to specialise in this class of work. He should also be conversant with modern methods of cold storage and refrigeration, and in the northern parts of the State in particular must give his attention to the economical construction of cool well-ventilated buildings in timber and iron.

Aspect and site, more particularly as regards levels, approaches, and drainage, are prime factors in planning ; for on them will depend whether the milk or cream will require to be mechanically elevated, or simply permitted to flow by gravitation through the course of its manufacture.

Briefly put, the general methods are as follow : The milk is received in cans on a platform, cart height, or elevated by hoists to a higher level (in rare instances it is pumped up, a course deservedly discredited), where it is weighed, a small portion being reserved for testing as to butter value, on which payments are made. It is then run into a receiving tank, and thence to the separator stage—being warmed in transit—where it is separated, the cream being pasteurised, cooled, and either gravitated, elevated, or pumped to ripening bats in cream-room, and the skim milk run to storage and delivery tanks for distribution or feeding purposes.

In the cream-room, ripening bacteria are added from the culture-room ; the former being lighted with a diffused light, and under control as regards temperature, so that the ripening may be hastened or retarded at will, and so placed that the cream may gravitate directly to churns in churning-room. After churning the butter is conveyed in trucks to the working-room, which should be also under control as regards tempera-

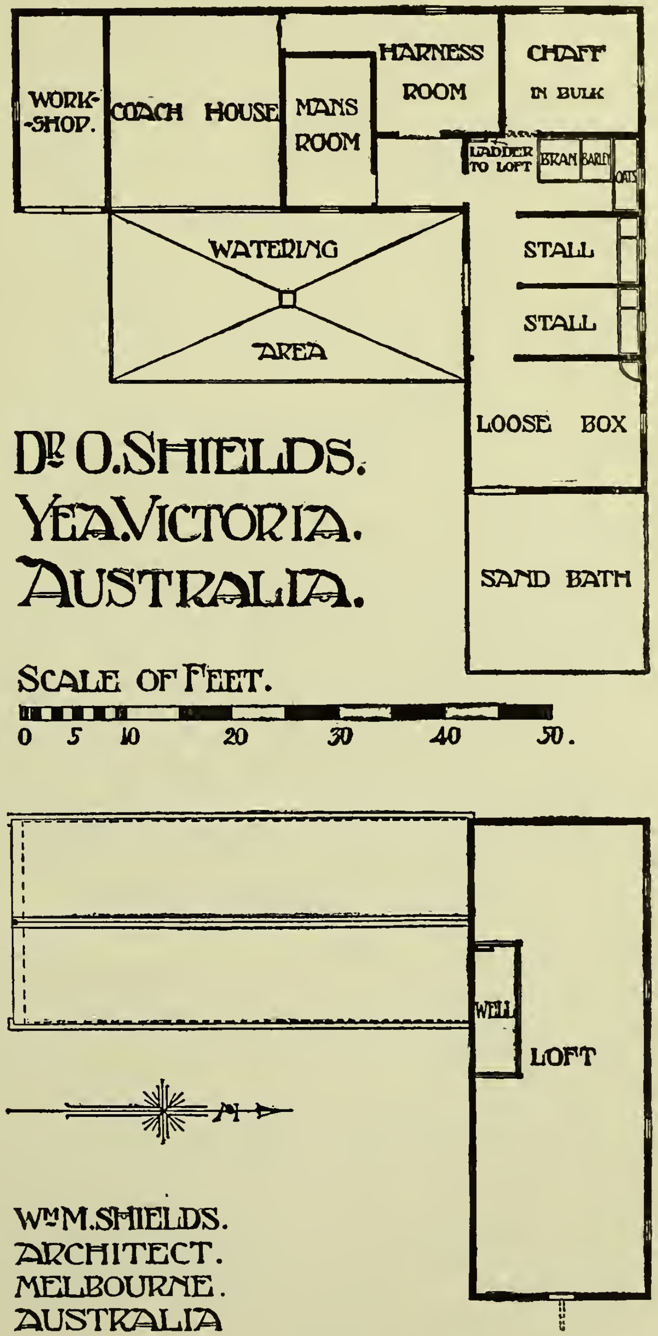


FIG. 226.

ture—the butter milk being drained to storage tanks as before. The butter is then worked and salted and eventually packed in boxes for export, or passed through the printer and weigher for home or local consumption. Cool storage-rooms with air locks and delivery slides, together with boxroom, general storeroom, manager's office, testing and culture rooms, with lavatory and

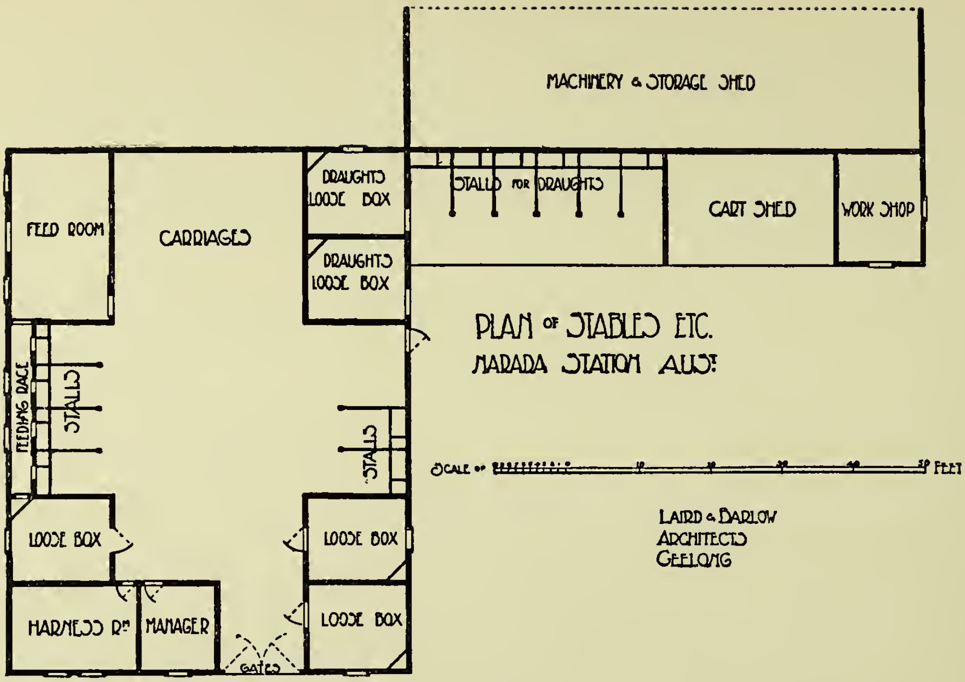


FIG. 227.

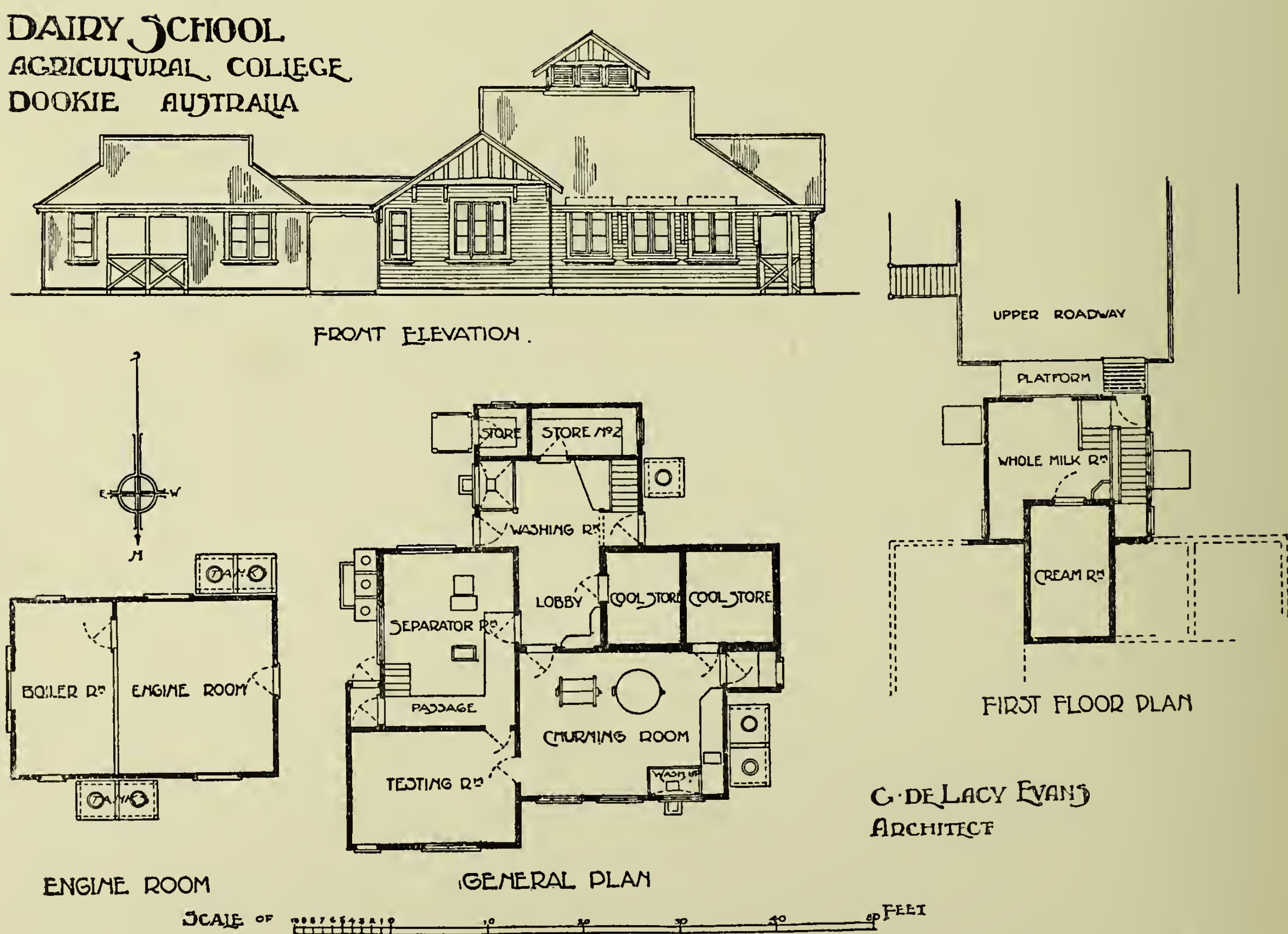


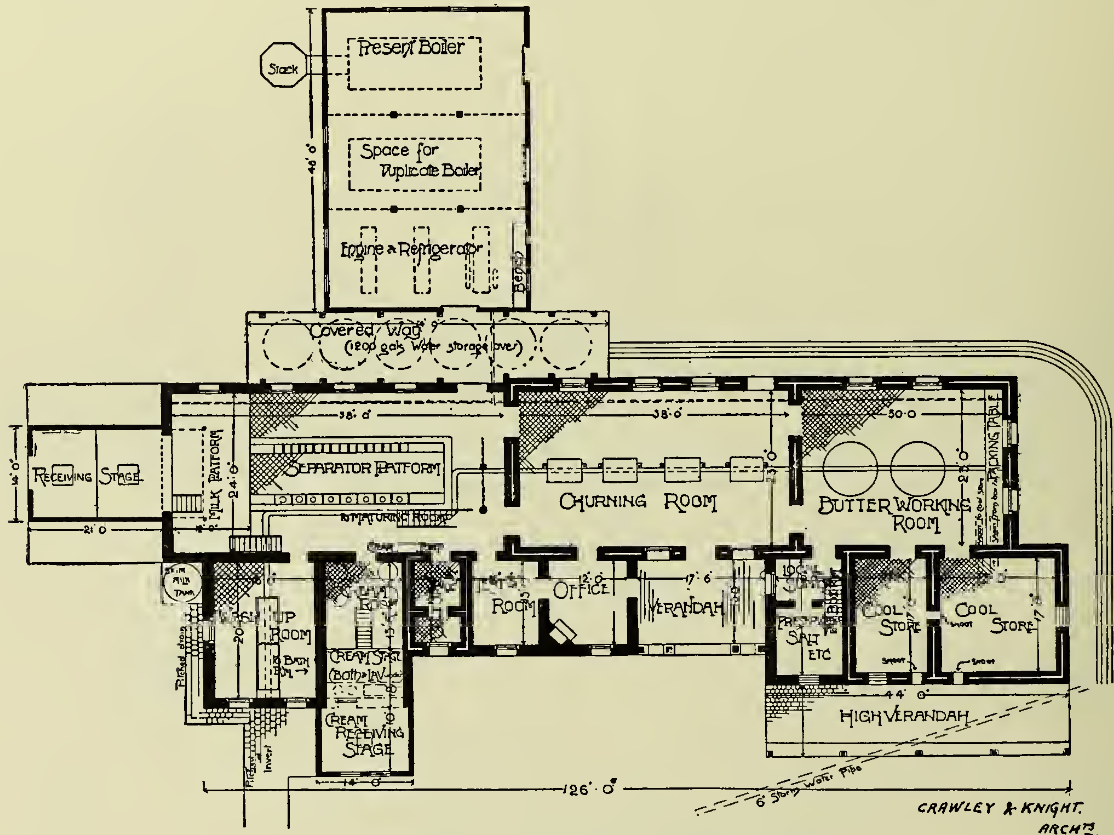
FIG. 228.

changing-room for employees should be provided for in the general arrangements. Engine and boiler-rooms should be planned, connected by covered way for access and housing of shafting and ammonia pipes; while provision must be made for condenser coils and cold filtered water storage for butter washing, etc.; and where water is scarce, arrangements must be contrived for spraying and cooling same after it has passed over the condenser, so that it may be used and re-used with a loss of evaporation only. All floors and walls must be washable, impervious to moisture and lactic acid, and capable of being flushed and dried by means of cross-air currents at will. All facilities for can-washing and receipt and delivery must be provided; and it is to be always remembered that economy in labour and handling are vital points in the planning and constructing of buildings of this class. The dairy school of the Agricultural College at Dookie (Figs. 228 and 229), designed by Mr. G. de Lacy Evans, F.R.V.I.A., to whom we are indebted for the above remarks, illustrates their application in Australian practice, the sketch being particularly valuable as showing how the upper roadway is banked up to the first-floor level.

Crude in design and arrangement, the first butter factories built in Victoria were all wooden frame buildings, 60 feet long by 20 feet, with a partition 20 feet from the south end, making a butter-working room 20 by 20 feet, the remainder serving as a separating and churning compartment. Right round the main structure was built a lean-to or skillion, divided at intervals so as to make a boiler and engine-room, wash-up room, coolroom, box and storeroom, office, and verandahs. The machinery, when it came, had to be fitted into this somehow. The building was altered and made to fit the plant. The proximity of the boiler to the cream and butter in the summer time materially assisted the hot winds in bringing about losses and trouble. Then a detached room had to be built, and the boiler removed to another position. So it was with nearly all the plant,—alterations had to be made each season, until a point was reached when the size of the different machines became known, and the relationship they bore to each other recognised.

Fig. 229.

The Grasmere Butter Factory (Fig. 230), designed by Messrs. Crawley & Knight, comprises the following rooms:—Engine and boiler-room (detached from main building), separator-room, churnroom, butter-working room, two coolrooms, maturing-room, preservative room, saltroom, boxroom, wash-up room, cream-room, bath-room, office, testing-room, and a culture-room. The grouping of the rooms is so arranged as to reduce the work of supervision to a minimum. The separator-room is 50 feet long by 24 wide, and has provision for eight separators. The churnroom is 38 by 23 feet, with provision for four churns. The churn posts are specially designed cast-iron columns, which carry the The skim-milk platform and tanks are placed very conveniently on the return to the road from the receiving stage, and are under the eye of employees working the hoists. The building throughout is well lighted and ventilated, some of the ventilators being specially designed with rubber and thumb-screw adjustments. The drainage of the factory is all above ground, the internal drainage being discharged by vitrified tile gutters, delivering into a pitched channel laid in cement outside. A septic tank is now in course of construction for dealing with the sewage. Between the engine-room and the main building there is an asphalt passage 11 feet wide, over which there is a tank stand having



GROUND PLAN OF GRASMERE BUTTER FACTORY.

FIG. 230.

floor of the maturing-room above. The butter-room is 30 feet by 23 feet, with a packing table the full width of room, on to the end of which a chute delivers the empty boxes from boxroom. A chute to cool-room is provided at the opposite end of the table for passing packed boxes through. The coolroom chutes have sliding sashes inside and out with rubber jambs, and eccentric bar adjustments; the cool doors are trebly double lined with insulated paper between, and have rubber jambs with screw adjustment fastenings. The wash-up room is 20 by 16 feet, with capacious slate wash troughs. There is a double milk-receiving stage in front of building, and a supplementary one at the side for receiving the cream from the creameries. storage for 10,000 gallons of water. The main shafting runs the whole length of the building, and there are small counter shafts for working hoists and pumping skim milk.

The accompanying plan of a Wool Shed (Fig. 231) is one that has lately been erected by Mr. Arthur Peck, F.R.V.I.A., of Melbourne, and is described as the centre-board plan,—that is, the shearers are placed on each side of the shearing board,—and is suitable for stations carrying from twenty to thirty thousand sheep. A great difference of opinion exists among station managers and sheep experts as to the best plan to be adopted. The building as shown stands about 4 feet from the ground-line to under side of floor joists, thus

giving access for men to clean out the sheep droppings; while it also allows for chutes to be constructed from the shearing board, thus enabling the shearer to place a shorn sheep through a trap door, when it slides to the ground and runs into the counting pen. The materials used in its construction are red gum, box, Murray pine, and Oregon. Situated in a district where the depredations of the white ant are very bad, the whole of the timbers with the exception of the Murray pine have been dipped in a solution known as arenarius, this being a preparation that preserves the timber from the ravages of the ant. The Murray pine, which is used for flooring and foundation piles, will resist the ant. The whole of the roofs, also walls, are covered with galvanised corrugated iron.

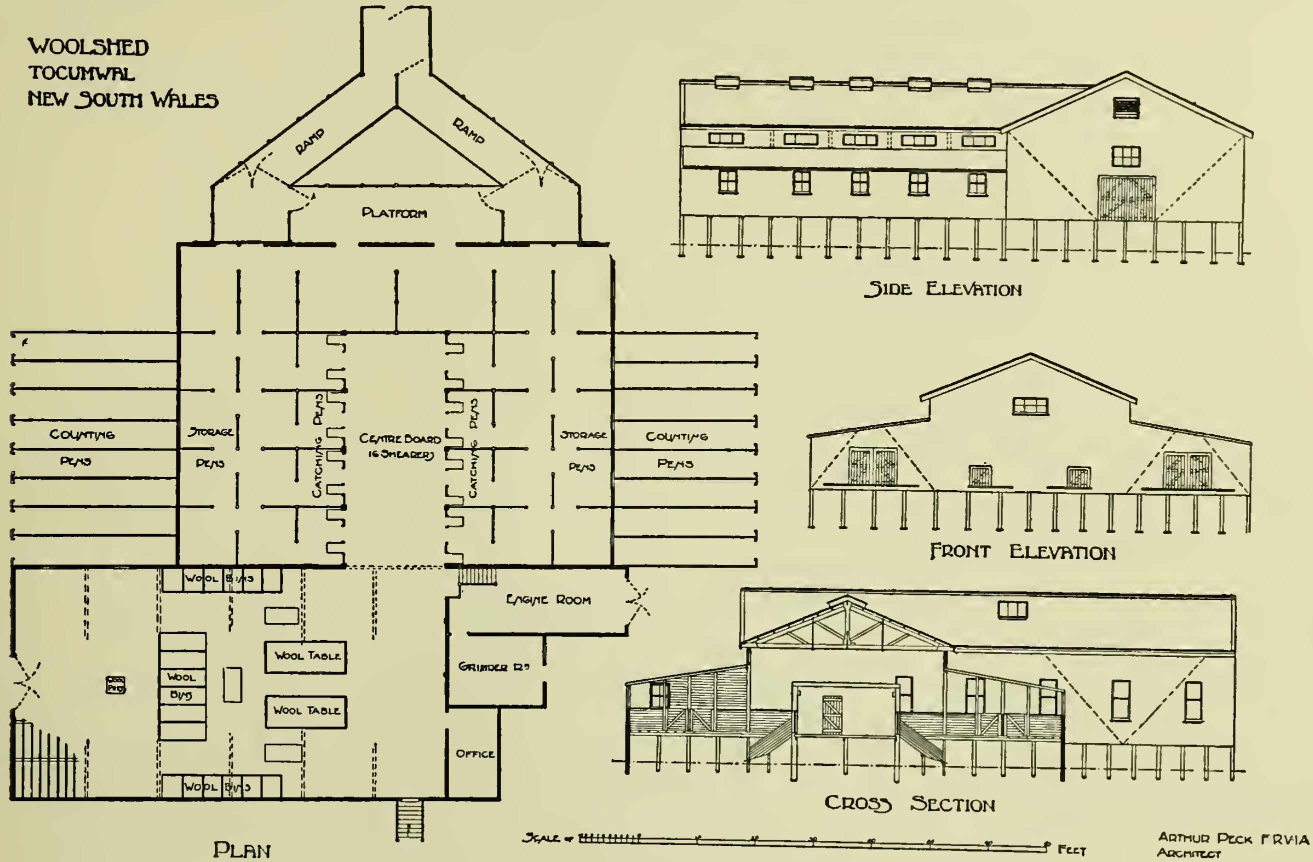


FIG. 231.

Fig. 232 illustrates an Australian wool shed of a smaller type at Narada, designed by Messrs. Laird & Barlow. The entrance for sheep is by means of an uprising race from the yards to the various pens which feed the shearing boards, which again have side gates to the outgoing races. In the woolroom are placed the sorting tables, bins, and presses, with large doors and a landing stage for the export of baled wool.

The demands of the bakery trade in Australia have required the designing and erection of a large number of well-equipped Bakeries, ranging from the one-oven bakery of the bush town or suburban shop to the extensive bakeries of large manufacturing firms. The one shown in Fig. 233 has been designed by Mr. Charles Kirkham and Mr. F. W. Thomas, architects, and is situated in Prahran (a suburb of Melbourne), to meet the requirements of a large catering business.

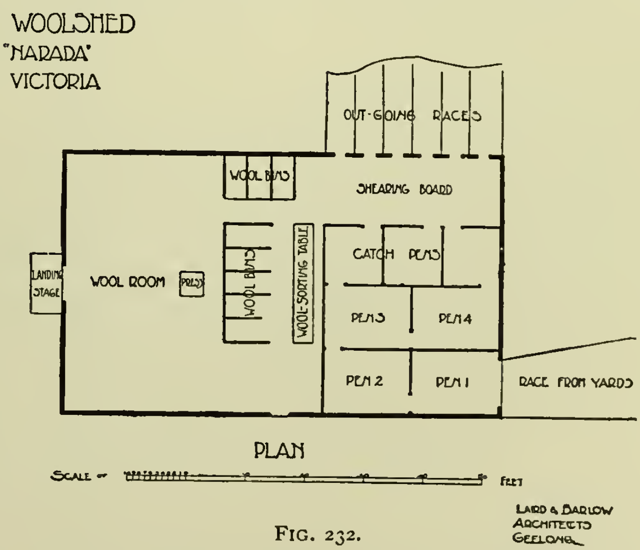


FIG. 232.

There are spacious and lofty working apartments on the ground floor, brick paved and equipped for the various processes of manufacture, one room being

specially set apart for confectionery. There are six ovens in all, in pairs, two being patent Stelda ovens imported from Düsseldorf, the others being brick furnace ovens. The spaces over the ovens up to the first floor have been made available for drying purposes required by the manufacturers, while there is large first-floor storage accommodation. In conjunction with the bakery proper, there is a shop and dwelling house, besides stabling and washing yards somewhat detached.

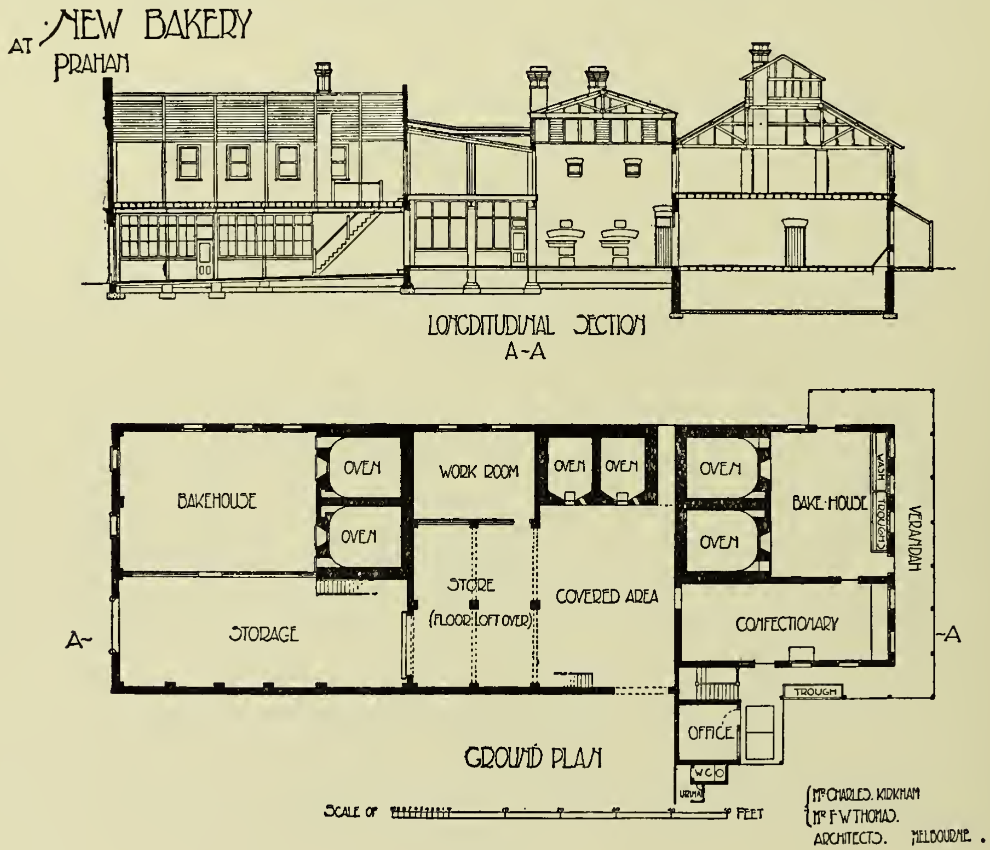
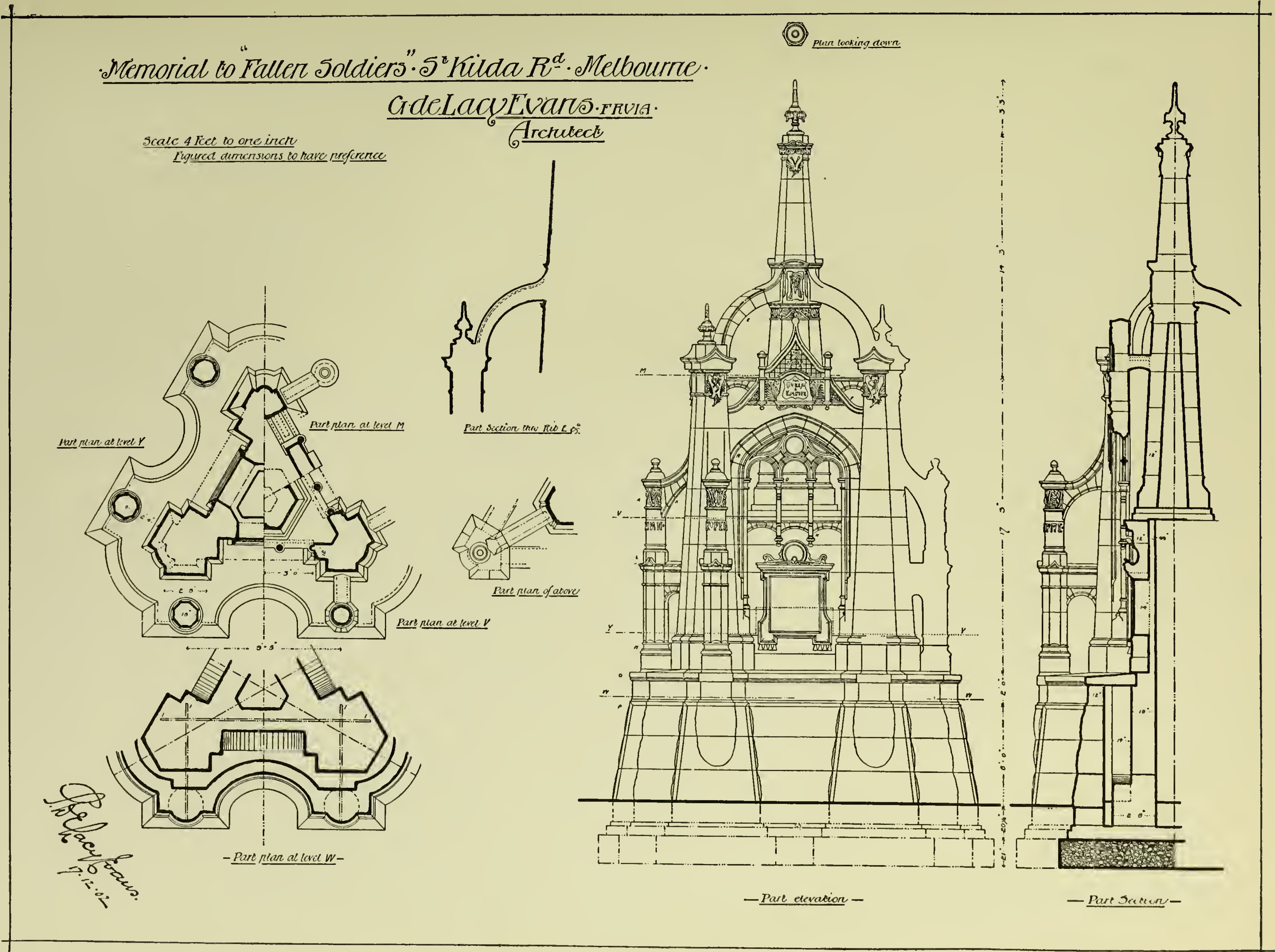


Fig. 233.

Memorials

Soon after the commencement of the late South African War, when it was found that the irregular soldiers of the "Britains over the Seas" were well fitted to successfully oppose the tactics of the enemy, a great wave of patriotic enthusiasm resulted in the despatch of colonial troops to fight side by side with those from the mother country. To commemorate the fact that they so fought, and that, fighting, many of them fell, monuments and memorials have since been erected in the various centres. The particular one selected for illustration, that in St. Kilda Road, Melbourne, designed by Mr. G. de Lacy Evans, F.R.V.I.A. (see Fig. 234), is situated in the most beautiful and important avenue to the city, and immediately opposite the Metropolitan Barracks and Military Headquarters.

It is a purely architectural memorial, rising to a height of over 40 feet; and is original in conception and treatment. Being an equilateral triangle on plan, the three faces are identical in design, differing in detail only; but every other point of view calls up unexpected effects of light and shade and grouping. It is constructed of a beautifully wrought rich brown sandstone (Pyrmont) on a bluestone (basaltic) base, with tablets of cast bronze. The details and carvings of conventional Australian foliage are very finely executed.



·Memorial to "Fallen Soldiers"· S^t Kilda R^d· Melbourne·
G de Lacy Evans·FRVIA·
Architect
Scale 4 Feet to one inch
Figured dimensions to have preference
Plan looking down
Part plan at level Y
Part plan at level M
Part Section thro Rib E.&c.
Part plan of above
Part plan at level V
9'·5"
Part plan at level W
Part elevation
Part Section
G. de Lacy Evans.
17·12·02

FIG. 234.

CHAPTER VI

AUSTRALIAN CONSTRUCTIONAL METHODS

(*Contributed by R. J. Haddon, F.R.V.I.A., F.S.A.I.A.*)

Masonry

Australia may be said to be rich in good building materials, none of the least of which are her varied and widely spread deposits of good workable building stone.

New South Wales Stone.—Practically the whole area of Sydney, with its hills around the harbour, is of rich sandstone formation. These Hawkesbury freestone deposits, as they are called, extend for many miles around, and are extensively worked for building purposes.

This permanent supply of easily quarried material has in a marked degree influenced the architecture of this fine city and its picturesque suburbs, where the stone for the building is often quarried from the site itself; and the formation of the country being for the most part hilly, this is scarcely a defect to a building site, rather in many cases does it prove of advantage, for the designer may not only consider the mass of the building, but may modify the structure of the hilly approaches.

The Pyrmont quarries are the most famous in Sydney, and have supplied stone for many years for some of the largest city buildings all over the continent.

The nature of this stone is medium in structure, and may be compared with some of the well-known Scotch freestones, such as one sees in Glasgow and other leading cities. Worked at moderate cost, and being of a warm buff colour that harmonises with the red brickwork so universally seen in Australia, and in tune with her clear atmosphere and blue skies, it has proved one of the most reliable materials for structural and decorative purposes. This stone can be obtained in blocks of great size for columns, landings, etc., and lends itself readily to mouldings and carvings, the method of dressing adopted being as follows:—

Bolstered and chiselled beds and joints;
Rubbed, tooled, or quarry-faced ashlar for general work;
Rubble for infilling.

Victorian Stone.—To the north and west of Melbourne stretches the great basalt country that has given Melbourne and her surrounding towns a sound hard bluestone. This is largely used for all purposes where special strength combined with hardness is required.

This stone is dark blue in colour, slightly honeycombed, and is obtainable in large sizes, the stones of largest dimensions and finest texture being produced from the Lethbridge quarries, about sixty miles from the capital city. A bluestone of a softer nature, much used for structural works (and sometimes built in colour contrast with imported freestones), is obtained from Malmesbury.

This material was largely used in public buildings in the early days, but has now been superseded to a very great extent by other materials on account of its sombre colour and excessive cost. Bluestone is, however, almost invariably used for window sills, thresholds, and stone stairs, forming in this way a most permanent and satisfactory material.

Of granite there is an unlimited supply, of a fine grey variety, obtained from Harcourt, about eighty miles north of Melbourne. This stone is seen in some of the largest city buildings, both in polished column, pilaster, and plinth work, as well as in fine patent axed ashlar. A red variety, also used, is obtainable from Gabo Island.

Stawell freestone should also be specially mentioned. This is a fine white sandstone, hard in working, but capable of very fine finish, and admirably suited for such buildings as the Victorian Parliament Houses, which have been erected of it. It is rich in silica, and the hardness of its working renders it very expensive for private use.

Other freestones include the Wawin Ponds free limestone and Barrabool Hills free sandstone. The former, of a warm buff colour, is largely used for dressings, and the latter, which is of a greenish colour, for general wall facings. This combination may be seen in the Melbourne Anglican Cathedral designed by the late Mr. Butterfield, and also in Ormond College at the University, at the Melbourne Technical College, and other important buildings.

Queensland Stone.—Queensland has produced good workable freestones, though the quarries for the most part are limited in extent and the best beds soon exhausted. The expense of carriage has also confined its use to the important buildings only, the general run of building being of brick.

In Brisbane the freestone most generally used is from the Helidon quarries, some sixty-five miles from the city. This stone is of fine texture, easily worked and good in colour, and has been used in the public offices and as rubbed ashlar in the Brisbane Railway Station. Yan Gan is another freestone now coming into use in the New Lands Office.

Porphyry is also quarried near Brisbane, and is used in foundations, base courses, plinths, and in coursed work or squared rubble. Of volcanic origin, it is hard and durable, and can be dressed with chisel or axed. Grey granite is also used.

Tasmanian Stone.—Tasmania produces good workable stones at moderate cost for general building, freestone from Kangaroo Point being in the opinion of some authorities the best freestone found in Australia. Analysis has given as much as 27.75 per cent. of silica. This stone has been somewhat extensively exported to the mainland, and is seen to advantage in the great Law Courts of Melbourne.

South Australian Stone.—South Australia has also a good stone supply, and many of the houses of Adelaide are built of stone.

The Mintaro slate from this part of Australia is one of the finest slates in the world, being even in colour and dense in texture, while it can be brought into the building in almost any size up to 10 feet square. It is therefore largely used for lavatory and general slab work, as also for curbing, paving, etc.

Fine coloured marbles are now also reaching the building markets, and some excellent specimens from New South Wales quarries are to be seen in city buildings.

West Australian Stone.—In and around the Westralian capital city of Perth, Cottisloe shell limestone is much used, while a variety of superior quality is worked in Rottnest, an adjacent island.

Good granites are also obtained in various parts of the State, while for goldfields work the Kanowna stone (a kind of decomposed granite) has been used in the Kalgoorlie public buildings and around the general district of Coolgardie.

Imported Stones.—Of imported stones, large quantities of Omaru soft white limestone have been used all over Australia, being easily worked and specially adapted for carving, and having the quality of hardening upon exposure. This stone has been extensively used in ecclesiastical work, especially in interiors, as in the high altar of St. Mary's R.C. Cathedral, Sydney, designed by the late Mr. W. W. Wardell, F.R.I.B.A.

Omaru stone is sawn into shape with hand saws, and steel dragged to fair surfaces.

Another New Zealand stone of much finer quality is a white limestone from Mount Somlis quarries, in Canterbury, New Zealand. From the same locality is also obtained a pink limestone which, in combination with the white stone, has been used with fine effect in one of the best designed city buildings in Australia in the perpendicular Gothic manner—Empire Buildings, Collins Street, Melbourne — subsequently altered and converted into insurance offices.

Brickwork

In such a large country as Australia there must needs be a great variation in the quality of bricks available for building, but while this is so it may be laid down as a general rule that the bricks are extremely good. Particularly is this the case with the steam-pressed machine-made Melbourne bricks, which for soundness combined with good uniform red colour can hardly be excelled.

These bricks are made from "Rock," which offers a surprise to the visitor who has in mind the clay digging, tempering, hack drying, and clamp burning of many of the English brickfields, though it is somewhat similar to that from which the Ruabon bricks are made. The popular term is "Reef," but this is, strictly speaking, not correct. These rocky formations are of such a character that when decomposed they become clay, and are taken by the brickmaker, ground, slightly wetted, steam pressed, and passed at once to the Hoffman kiln, from which they emerge sound, hard, and durable, weighing about 8¾ lbs. each. They are put upon the market at about 38s. per thousand.

With bricks of this character Melbourne has been provided with 120,000 houses, large buildings, and stores. And what is true of Melbourne is also in a somewhat lesser degree true of the other leading cities.

In country districts there are scattered brickfields, working for the most part on more primitive lines with hand presses and ordinary kilns.

So far there has been a somewhat limited use of the moulded brick. This has been partly due to the excessive hardness of the brick-making materials, and the consequent difficulty in cutting and adjusting small returns, angles, and special parts required to properly complete any intricate design. Of late years, however, this field of production has been considerably opened up, and the manufacture of excellent architectural terra cotta, within range both of Melbourne and Sydney, has made purely brick treatment in design possible.

The general colour of the Australian brick is red, but for decorative purposes white bricks are made in limited quantities, and a very good quality of dark brown brick is also manufactured from material highly charged with iron. There is nothing in Australia, however, to correspond in colour with the London stock brick.

In the execution of brickwork the London practice is generally followed with regard to wall thickness, footings, etc. In the cities, where the Building Acts are mostly based upon the London laws, this is specially the case. There is, however, a very marked preference for the hollow wall rather than that of a solid character, on account of excessive heat and heavy rains, it having been found that a 2-inch cavity has a marked influence in reducing temperature and securing internal freedom

from dampness. This hollow wall work leads to the use of garden-wall bond, and the adoption of the stout galvanised wire or hoop iron tie, the cast-iron variety being but little used.

For solid work of a heavy character, English bond is

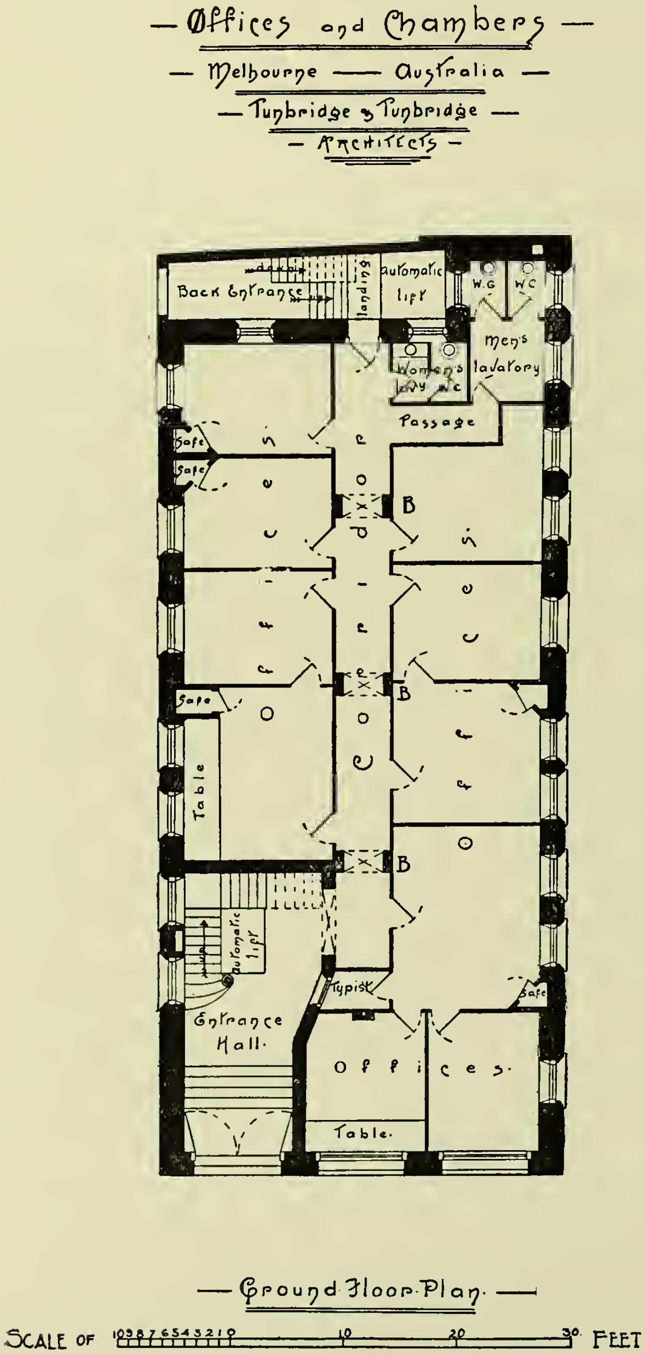


Fig. 235.

used, as well as a variety called "Colonial Bond," consisting of three rows of stretchers and one row of headers, which makes easily laid, sound walling for warehouse work.

Flemish bond is used for the best class of facing work where solid walls are required.

Mortar

Australia has excellent limes of all kinds, and creek sand is generally available, while there are also good colonial cements.

Grouting is more often resorted to than in English work, the "Billy can" being quite a bricklayer's tool, as are also the bolstering chisel, heavy hammer, and special brick hammer made necessary by the hardness of the bricks, which are often beyond the range of trowel cutting.

The joints follow the usual range of flat, cut and struck, ruled and cut, weathered, etc., a beaded joint being much seen of late years.

The London practice of raking out the face joints and pointing in cement is but little seen; in so dry a climate this is perhaps not necessary. Some good work has been done with a slate-coloured joint formed with black foundry sand and dark lime, which sets very hard and lends solidity of colour to the red brickwork.

Armoured Concrete

The plan given in Fig. 235 is that of an important building carried out entirely, as far as its interior proportions are concerned, in armoured concrete, the outer walls alone being of brick.

The building, designed by Messrs. Tunbridge & Tunbridge, consists of six storeys and a basement with a flat roof above, which is used for offices and residential flats.

The general principle of construction is that of the erection of a series of double vertical columns flanking the centre corridor, supporting longitudinal girders, which in turn support transverse girders receiving the floors and partitions. The method of construction consists first in the placing in position of a network of commercial round bars (no twisted or deformed bars employed), steel being preferred in some cases, although reinforced members wholly in tension have iron freely used in them.

In the proportioning of reinforcements more than usual attention was paid to adhesive stresses as distinguished from direct tensile stresses. For this reason the bars used were in large numbers of small diameter, no bars even in the heaviest girders being greater than 1¼-inch diameter.

The standard proportions of concrete used for all members subject to cross bending was one part of Australian Portland cement, two parts of sand, and three or four parts of basaltic screenings from ½ to ¾-inch gauge. The concrete was invariably mixed as a "very wet" mixture, being of such a liquid consistency as to be freely poured, and requiring very little ramming for its complete consolidation.

The building has plan dimensions of 80 by 37 feet.

The whole of the supporting girders and joists, the

columns and their footings, the stairways, the safes, the lintels, and the whole of the interior walls are one monolithic mass of concrete scientifically reinforced in every direction, of which a detail is given in Fig. 236. The floors are but 3 inches thick, and the interior walls only $2\frac{1}{2}$ inches, thus providing a building which, while in a high degree fireproof, is constructed of imperishable materials of great rigidity, vermin proof, and most economic of space.

Upon the temporary wood casings being removed it was found that the surfaces were so smooth as to render but little surface plastering necessary, a thin coat of American rock wall plaster being used.

The floors are laid with heavy linoleum secured with mastic to the concrete surfaces.

Other important works are now in course of erection in this manner in various parts of Australia, and the armoured concrete has found much favour in engineering works.

sharp creek or frankstone sand to one part of approved English Portland cement.

"Second coat (finishing) to be composed of two and a half parts of well-washed white fine sand to one part of Alsens (German) cement.

"First coat to be $\frac{5}{8}$ inch thick, finishing coat $\frac{1}{4}$ inch thick. No more stuff to be made up than can be used in one day.

"Keep work damp for at least a week after completion.

"Model all enrichments in clay, form moulds in plaster, cast and execute in pressed cement, and fix firmly in position on the work.

"Run all moulds, cornices, architraves, etc., to detail."

For general internal plastering in Melbourne the following Specification may be taken as a good workable one:—

"Laths.—American laths to be used for walls, colonial cut American for ceilings, fixed with 18-inch breaks, and all well nailed with lath nails.

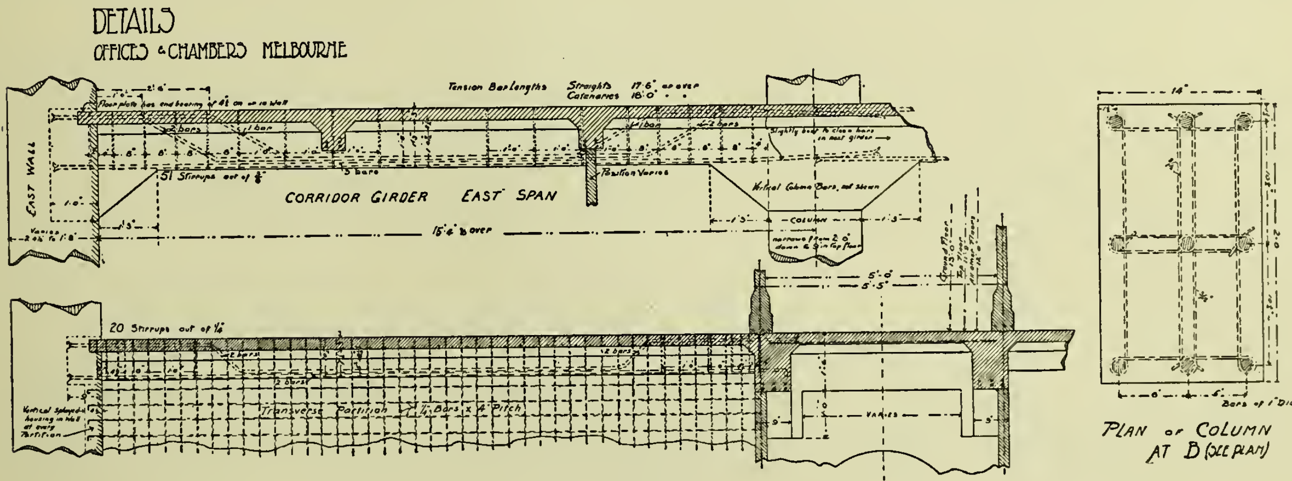


Fig. 236.

Plastering

The trade of the plasterer has found considerable scope in Australia, especially for outside work. This is much to be noticed in the brick areas where stone has been too dear to use in a general way for facings. Many fine examples of extensive stucco buildings are to be seen in the cities.

The difficulties of the work differ in degree from those of English work. "Frost," the great enemy of the plasterer, is but little in evidence in Australia, whereas the hot dry weather, and especially the extremely hot winds, create conditions entirely opposed to the execution of sound work in the summer months. A clause in specifying is often worded thus—"No work to be executed on any hot-wind day."

The following may be taken as a brief Specification for general outside stucco in Melbourne:—

"Well wet all brick surfaces, and keep work moist throughout.

"First coat (floating) to be composed of four parts

"First coat to be composed of three parts of good sharp creek or frankstone sand to one part of Heads or Waratah lime, run through $\frac{1}{4}$-inch mesh sieve, mixed with good long well-beaten cow hair in the proportion of $\frac{1}{4}$ bag of hair to 3 bags of lime.

"Second coat (floating) to be composed of four parts of sand as above to one part of ditto lime, together with a small quantity of well-beaten cow hair.

"Third coat (setting stuff) to be composed of three parts of Lilydale lime to one part of clean white sand, washed through a fine sieve."

If work is to be finished very white it is customary to use Lilydale lime and plaster of Paris in the proportion of four parts of lime putty to one part of plaster. This material is also used for running cornices.

All external angles should be backed in with English Portland cement and sand 4 to 1, and finished $\frac{1}{8}$ inch thick with pure Keen's cement to smooth faces, as is customary in England.

In present-day practice, stamped embossed zinc and

mild steel ceilings and cornices, both imported and locally manufactured, have to a great extent superseded the use of plaster for ceilings. This, together with the increasing use of locally made fibrous ceilings, which are made in sections and screwed in position, has had a marked effect upon the general plastering work, so far as internal treatment is concerned.

Tiling and Slating

The roof coverings in most general use in Australia are slates, tiles, galvanised iron, and native wood shingles. Tiles have been manufactured in the country,

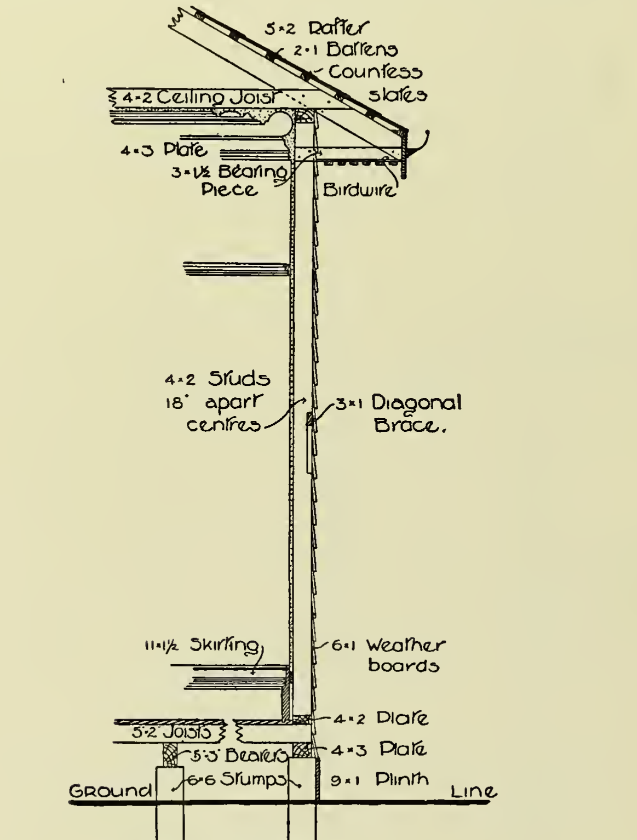


Fig. 237.

but the market (which is a considerable one) is held by imported French Marseilles tiles of various brands. These tiles cover well, and have the advantage of securing the passage of air in and out of the roof space. The tiles are set close, to interlock both side and end, and are secured to battens with copper wire, the cost being about 47s. per square for tiles and battens fixed complete.

The best slates are those imported from Wales, both blue and pink, 20 by 10 inches costing about £13 per thousand. Unfading green Vermont (American) slates are also much used, being good in colour for red-brick buildings.

Partly for economy and specially for purposes of water conservation, galvanised iron roofs are largely availed of.

Shingles of peppermint and other splitting gums make excellent and picturesque roof coverings, with their grey weathered sheen, and last for many years. The danger of fire is, however, much against their use in districts subject to the ravages of bush fires.

Carpentry and Joinery

There are two general divisions in the native building woods of Australia—the gums and the pines, the gums being by far the greater in importance for building purposes. The great gum (eucalyptus) forests, "the Bush," cover the greater part of the continent, and the settlers have cut into these vastnesses to found their cities and build their settlements. Thus year by year the forests have been pressed back, and the materials from the mills have increased in price owing to heavier freights and handling charges.

The pines have but a limited output for building purposes, and, as the demand for this class of timber is considerable, large quantities are imported into the Commonwealth. The principal native pines are those found in Queensland, and known generally as Queensland pine, and the Murray pines from New South Wales. These are supplemented by the importation of Kauri pine from New Zealand, and by finishing woods from various parts of the world, the principal among which being red Californian pine, Baltic pine, American walnut, oak, ash, etc.

For structural timbers the native woods are largely used, the exception being in best class roof and wood-framing work, where imported Oregon is generally preferred.

The jarrah of Western Australia, a dark red heavy timber, is used both structurally and for finishing, and looks well when oiled or polished.

Hard wood is used for framing houses, ground-floor joists, and the cheaper class of roofs, etc. When carefully selected and dried it makes good flooring with an oaklike finish.

Red gum, a dense red wood somewhat like jarrah in appearance, is an excellent material for all purposes when sunk into the ground. It is therefore much used in the Eastern States for floor bearers, plates, stumps, and in fencing posts, etc.

The country produces a large variety of beautiful show woods for panelling and special joinery work, among which may be mentioned—blackwood, Huon pine, beamwood, silky oak, etc.

With these materials, highly skilled labour, and wealthy demand, excellent work in carpentry and joinery has been done in Australia, the practice as a whole proceeding much upon English lines.

A detail section is given in Fig. 237 of an ordinary wood villa building as used in Australia. The structure, if in Western Australia, would probably be all of

jarrah; in other parts of Australia a more general Specification would be as follows:—

"All timber in or near ground, red gum.

"Stumps 4 feet 6 inches apart centres (these are sunk in ground to necessary depths, and have sole plates under). Along the top of the stumps all around outside of building is a 4 × 3-inch plate, the joists on inside of building being supported by the 5 × 3-inch bearer.

next ground on to 9 × 1-inch red gum plinth, and at all angles setting fair against 2 × 1¼-inch stops."

The detail given in Fig. 238 shows a verandah of the usual Australian type, where the main roof of the villa continues down to form the verandah roof, the whole being covered with French Marseilles tiles, copper wired on to deal battens. Oregon pine is generally used for rafters, spaced 18 inches apart centres, the

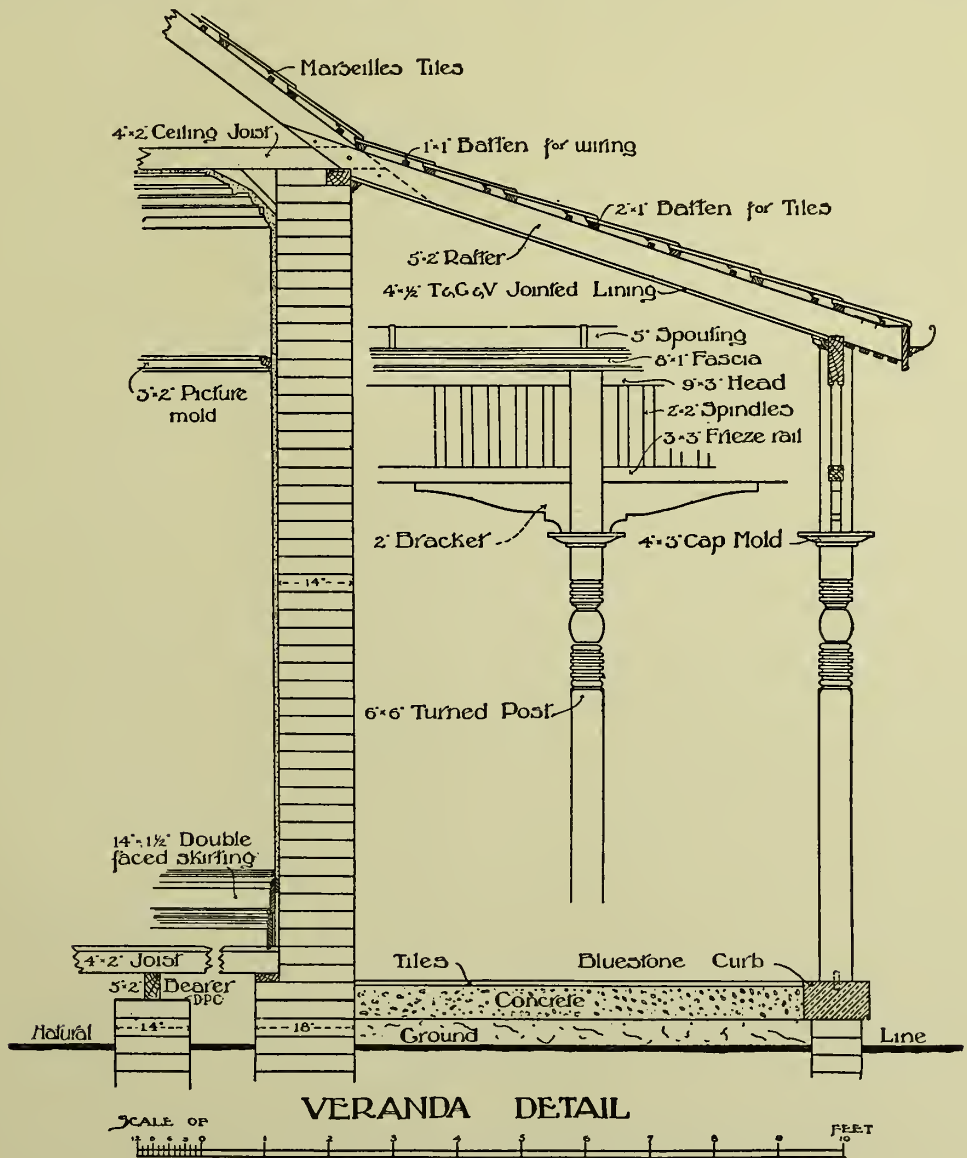


FIG. 238.

"Floor joists of 5 × 2-inch hard wood, 18-inch apart centres, receiving 6 × 1⅛-inch T. & G. dry hard wood flooring. Hard-wood studs for walls, 18 inches apart centres, tenoned into top and bottom plates and diagonally braced outside, with 3 × 1-inch H.W. braces cut in. There is a 4 × 3-inch top-plate and joists and rafters, eaves, etc., as shown. Spouting of 22 gauge galvanised iron. The external faces lined with 6-inch feather edge weather boards having 1½-inch lap, finishing

under-side lining being of 4 by ½-inch tongued and grooved and V-jointed Kauri (New Zealand) pine boarding.

Posts may be, as also all other exposed woodwork, of redwood (American) or of jarrah.

Posts, 8 feet apart centres, dowelled with galvanised iron gas piping into hard bluestone curb, turned where shown with moulded and mitred caps, housed into brackets and frieze rail; the 9 by 3 inch-head to be

continuous and forked through upper portion of posts and bolted. Square spindles stub-tenoned in. Fascia 8 by 1 inch beaded with batten lined soffit; spouting out of 22 gauge galvanised sheet iron secured with stout hoop iron straps riveted on. Floor of Australian made tiles from Mitchan, Victoria.

Shoring and Under-Pinning

In a new country like Australia the architectural practice among old and dangerous structures is limited, the work lying rather with new buildings upon virgin sites. With alterations, however, the architect has often much to do, owing to the rapidly growing demands of business and commerce.

For shoring, Oregon (American) timber is generally used, being found best for this class of work. Of late years there has been a growing tendency to supplant timber needles with those of steel. Short lengths of rolled steel joists, taking up much less room and needing less cutting for their insertion through walls, present many advantages over the older method.

Much is also done by cutting out 4½-inch thicknesses of walls, and rolling in horizontally laid steel joists, one by one, to take overhead weights (the working being from both sides of wall), afterwards cutting the required openings below. By this method shoring is altogether avoided if the old brickwork be strong in adhesive quality.

Plumbing

It may be taken as characteristic of Australian plumbing work that much less lead is used than in Britain, the excessive and sudden changes of temperature being most destructive to this material.

In place of lead, galvanised iron has come into general use even in good class work. For gutters, heavy gauge galvanised, specially flatted sheet iron, double riveted and double soldered at all jointings, turned up against walls and well under roof coverings, and left free for expansion and contraction, is generally found to be the best.

Lead wastes, too, are much inclined to creep, and if carried along walls often sag in swag-like loops where exposed to high temperatures. Galvanised welded tubing, glass-enamelled inside, is therefore largely used for soil pipes, wastes, etc., and brass and iron are growing in favour for sanitary traps and small fitments.

For eaves spoutings, rain-water pipes, roof ventilators, and for many other general purposes in outside building, the practice is for galvanised sheet iron to be used.

In sanitary plumbing, Australia has presented some interesting practice. With extensive modern sewerage systems in Sydney, Melbourne, Adelaide, and smaller systems in other cities, the peculiar needs of climate have found marked expression in the work, and for data the student would do well to study the systems of working adopted by the authorities controlling these works.

Though lacking in æsthetic qualities, galvanised iron as a roof covering has been a most practical boon to the country settlers of Australia, where the all-important problem of water supply is ever present.

This material has therefore become the general roof material in the country districts, and is in its corrugated form largely imported, the general lengths being from 5 to 10 feet, with 26 and 24 as general gauges. The fixing is generally by means of galvanised screws through each alternate corrugation to under-side battens about 24 to 30 inches apart. End lap is from 6 to 9 inches, according to pitch of roof, with 1½-inch corrugation side lap. Hips, ridges, and valleys are all made of galvanised sheet iron, and are riveted and soldered together in position, the whole making a light, durable, and weather-tight covering.

Painting and Glazing

It may be taken as characteristic of the painter's craft in Australia that the excessive heat and sudden changes of temperature, which open and close the wood, are much more destructive to his work than the more temperate climate of England. Burning off is therefore more frequently resorted to, and dark colours avoided for outside work; white, stone, and the general range of sienna colours alone being of the class that really withstand the excessive heat.

The bleaching effect of strong sunlight has also to be reckoned with when colour is used either externally or internally, and this leads to frequent renewal of the work should transient colours be employed.

The best English and Scotch white leads and materials still command the market in the best practice, though colouring earths, oxides, and white leads are all produced in a limited quantity in Australia.

For glazing, Australians generally prefer large sheet glass, though coloured leaded glass finds much favour for special purposes.

In Queensland and those tropical zones visited by heavy hailstorms, skylights of all kinds have to be strictly avoided, and it is not infrequent for the ice to be so strong and cutting as to completely perforate and honeycomb ordinary galvanised iron roofing.

For skylights in the Southern States, heavy glass with wire bedded in has been found to be the best, such a combination avoiding the accumulation of dust, which is an element to be reckoned with in all Australian towns.

Lighting

In the newly settled parts of Australia, such as on the goldfields of Western Australia, where towns have been literally born in a day and cities created in a few years, electric lighting is often the first public lighting to be adopted, the most modern appliances being forthwith planted in the midst of lands which a few years ago only knew the savage.

With gas at 5s. per 1000 feet and electricity at 5d. a unit in Melbourne, and 6d. in the suburbs, it will be seen that electricity has a far better chance of competing with gas than, say, in London, where gas is less than half the price and electricity about the same as here. The increased advantages obtained both in illumination and cost by the use of the incandescent gas mantles has been met by the counter use of such electric lamps as the Nernst, Tantalum, Osman, etc., which cut the cost by about 60 per cent. on the ordinary incandescent electric lamps.

The incandescent gas mantle has brought ordinary coal gas much more keenly into competition with electricity than formerly, and the favour ebbs and flows between the one and the other, especially for street and shop lighting.

The value of acetylene lighting is well marked in many of the country houses of Australia, which are by this means, though separated from town often by very great distances, able to manufacture an excellent lighting medium which has the double advantage of being able with proper apparatus to be used also for domestic heating purposes.

Heating and Ventilation

In comparing American with Australian planning, one is at once struck with the influence which the warming problem has upon the former work, an influence that often absolutely alters the scheme of arrangement and leaves but little in common between American planning and that required in a hotter climate.

The Australian practitioner is more often faced with the difficulty of *cooling* rather than heating his building, and away up north, in Queensland and parts of Western Australia, is often seen the strange sight of houses without chimneys at all, fires being unnecessary for warming purposes.

It may be taken, then, as an Australian problem, how to keep the building cool when the hot winds rage outside, and insect pests and dust have to be planned against.

In the scheme of ventilation, therefore, we find lofty apartments, wide verandahs, outside venetian shutters, fly-wire doors and windows, and hollow walls, while cross passages and fanlights over internal doors are often arranged to cause through currents of air.

In spells of sudden excessively hot weather the building should be made to withstand in a degree the great outside temperature until the change comes, when it should be readily opened to allow of the free passage of cooling air.

The ventilation of public buildings is in some parts of the continent regulated by law, noticeably throughout Victoria, where the Central Board of Health has the following requirements (see Fig. 239):—

"*Ventilation.*—Every compartment of the buildings (including passages) must be separately ventilated. If an approved artificial system of ventilation is not adopted provision must be made. The inlets must be shafts, tubes, or hoppers opening slantingly upwards into the compartment through the external walls (either through the walls themselves or through the windows in the walls). They must as far as practicable be equally distributed along the external sides and ends of each compartment. The upper edges of their external openings must be from 3 to 5 feet 6 inches, and the lower edges of their internal openings and (where hoppers are provided) the upper edge or mouth of hopper must be from 6 feet 6 inches to 7 feet above

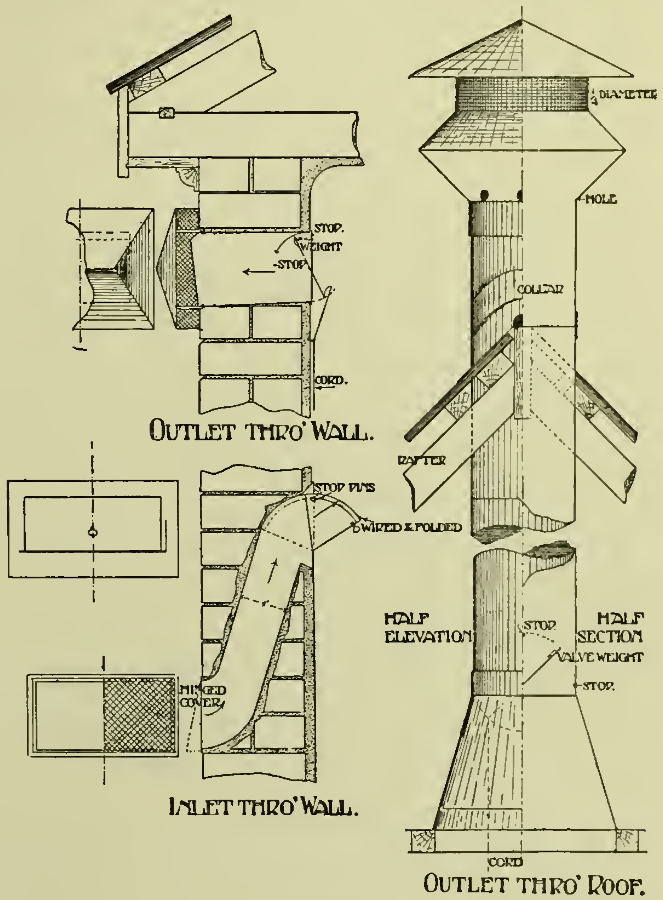


Fig. 239.

the level of the floor of the compartment to be ventilated.

"*The Outlets* must be openings in the ceilings or roof lining. They must not open into the roof space, but each of them must be continued through the roof space and through the roof itself by means of a shaft or tube having a transverse area at least equal to that required for the opening (in the ceiling or roof lining) over which it is placed, and having its upper end so constructed and so protected by a cowl or shield or other appliance as to prevent the entry of rain.

"For a building consisting only of one floor (the ground floor), and for the uppermost storey of any building consisting of more than the ground floor, one-third of the area of the outlets may be provided by

means of openings situated immediately below the wall-plates extending through the external walls and properly shielded outside; and from each floor but the uppermost of a building consisting of more than the ground floor, the outlets for each may be entirely provided by such means.

"All air shafts, tubes, and openings, whether for inlet or outlet of air, must be constructed so as to be readily cleaned out, and must not communicate with any cavity or space in the thickness of the wall, nor with the space intervening between the ceiling and the floor and roof covering over, and the inlets must in addition be fitted with regulating valves for opening and closing them in varying degrees.

"The clear air-way (*i.e.* the sectional area of the most contracted part of the ventilators, grating bars and such obstructions being therefore excluded) must be, for inlets, at least 2 square inches, and for outlets 2 square inches for every 4 square feet of floor area, except as regards existing buildings and weather-boarded buildings lined with match board lining only, in which the amount of ventilation to be provided in each case may be modified. Perforated zinc must not be fixed to either inlet or outlet vents, and wire gratings must not be less than $\frac{3}{4}$-inch mesh.

"The clear air-way for any one inlet should not exceed 50 square inches, nor for any outlet be more than 170 square inches.

"No opening into the roof space will be allowed to supply means of communication between such space and the interior of the building.

"The space between the surface of the ground and the floor of the building must be amply ventilated."

In rural Australia the great log fires for winter evenings will always remain the classic mode of heating. In the cities the large open fireplace is more often a home idea of the owner, but little required in a new land of milder climatic conditions.

In institutions, hot-water radiation finds considerable favour for many reasons of cleanliness and economy of spacing, while electric radiators are increasingly used with the laying down of electric plants.

OUTLINE SPECIFICATION (FOR WESTERN AUSTRALIAN WORK)

Materials

P.C. Values.—The specified "P.C." values are the net cost of the articles at the manufacturers in England, unless otherwise described.

Water.—Water shall be clean and free from salt.

Sand.—Sand shall be clean, sharp, coarse, virgin pit, free from loam, impurities, or salt.

Washed sand.—Sand for the cement rendering shall be well washed.

Lime.—Lime shall be fresh burned stone, free from core.

Cement.—Cement shall be "Portland," of English manufacture, and of an approved brand; and shall weigh 112 lbs. to the imperial bushel, and be capable of bearing a strain of 300 lbs. to the square inch on a moulded briquette seven days old, set in water. No cement shall be opened out except in the presence of the overseer.[1]

Concrete.—Concrete for foundations shall be composed of one part cement to two parts sand and six parts approved stone, broken to pass through a 2-inch ring, and screened; or in lieu of the stone, clean, washed, approved gravel may be used. It shall be mixed on a water-tight sheltered board, watered through a fine "rose" nozzle, turned over once dry and twice wet, and laid in and rammed.

Concrete for floors, door steps, and hearths shall be composed of one part cement to two parts sand and four parts stone, broken to pass through a $1\frac{1}{2}$-inch ring, or gravel, and mixed, etc., as previously described.

Coke concrete shall be composed of one part cement to two parts sand and three parts breeze, or coke, broken to pass through a $1\frac{1}{2}$-inch ring. The coke shall be washed free of dust. The cement and sand shall be first thoroughly mixed dry, the coke then added, and all turned over once dry and twice wet, and as previously described for other concrete, and laid in position.

Cement rendering.—Cement rendering for floors shall be composed of one part cement and two parts sand, and for walls one part cement and four parts sand, and used fresh.

Cement mortar.—Cement mortar shall be of one part cement to four parts sand, and used fresh.

Lime mortar.—Lime mortar shall be, by measure, of one part lime and two parts sand.

Plaster.—The coarse stuff shall be of $\frac{1}{3}$ slacked and sieved lime, and $\frac{2}{3}$ sand, with 9 lbs. of hair to each cubic yard of stuff. Fine stuff $\frac{1}{2}$ lime and $\frac{1}{2}$ sand. Gauged stuff shall be $\frac{4}{5}$ fine stuff and $\frac{1}{5}$ plaster.

Stucco.—Stucco shall be $\frac{3}{4}$ fine stuff and $\frac{1}{4}$ fine white sand.

Hair.—Hair shall be best strong cow hair, long, well beaten, and free from grease.

Laths.—Laths shall be stout split jarrah.

Damp-proof course.—Damp-proof course shall be composed of "rock bitumen" and sand, or of approved asphalt.

Drain pipes.—Drain pipes shall be glazed earthenware socket pipes of clean bore, with proper junctions, bends, and special pieces, laid to a grade of not less than 1 in 144, unless otherwise described, jointed in puddled clay and pointed in cement.

Stone.—Stone shall be good, hard, solid, flat-bedded; the best procurable within ...... miles of the building site. Stones shall be large in size, and laid on their

[1] This is an old-fashioned and inadequate specification, now giving way in England to that of the Engineering Standards Committee.—ED.

natural beds, and well wetted before being set in the work.

Bricks.—Bricks shall be of the best description, square, hard burned, in size not exceeding 9 by $4\frac{1}{2}$ by 3 inches. Soft, unsound, ill burned, or broken bricks shall not be delivered on the works. The bricks for facing the external walls shall be picked of an even colour. *Fire-clay bricks* shall be of the best "Staffordshire," or of an equal manufacture.

Timber and deals.—The carpenter's work shall be executed in jarrah timber, unless otherwise specified, of the best quality, die square, free from heart wood or other defects. The *Joinery* shall be of jarrah, unless otherwise specified, free from heart wood, shakes, sap, or other defects, and thoroughly seasoned. *Deals* for joinery shall be of yellow Baltic or American pine, free from sap, shakes, large or dead knots, or other defects. All timber shall be obtained before the expiration of one-fifth of the contract time, and stacked upon the ground. All sizes figured or specified are the finished sizes in work.

Nails and spikes.—Nails shall be strong wire, and in length equal to $2\frac{1}{2}$ times the thickness of the first board or timber through which they are driven; and for lapped boards or timbers the nails shall be as last with the thickness of the second timber added to the length. Spikes shall be stout wire, in length equal to twice the thickness of the first timber through which they are driven.

Glue.—Glue shall be of the best "Scotch."

Iron.—Castings shall be of good grey iron mixed with a proper proportion of scrap; and shall be clean, sharp, free from air bubbles and other defects.

Bolts, nuts, washers, straps, and all other wrought iron shall be of B.B. Crown, or other approved quality. Bolts not otherwise specified shall have square heads and nuts with washers; the threads shall be clean cut, and of Whitworth's standard. All the wrought iron-work shall be heated and dipped while hot into boiled linseed oil.

Ironmongery.—All the ironmongery shall be of the best quality and of an approved manufacture, and any which is specified to be of a particular make shall be ordered by the contractor from the manufacturer within one week of the signing of the contract, and no substitutes of other manufacture will be accepted.

Galvanised iron.—The galvanised iron shall be of English manufacture, and of an approved brand, and free from all defects.

The galvanised corrugated iron for roof covering shall be No. 24 B.W.G.

Eaves gutters, rain-water pipes, and cappings.—The galvanised iron for eaves guttering, rain-water down pipes, and cappings shall be No. 24 B.W.G.

The ridge and hip cappings shall be 16 inches wide with roll, and 3-inch edgings added of 4 lbs. lead.

Air gratings.—The air gratings on outside of walls shall be galvanised cast iron, and on the inside of walls galvanised cast iron, 9 by 6 inches, or plaster panels.

Zinc and lead.—Zinc shall be No. 12 malleable, weighing 18 ounces per superficial foot; and the lead shall be milled, weighing 5 lbs. per superficial foot, unless otherwise specified.

Paint and putty.—The paint shall be composed of genuine white lead or zinc, with linseed oil, turpentine, and driers in proper proportions, and finished to selected colours and tints. Raw oil shall be used for the inside work, and boiled oil for the outside. The putty shall be of the best London whiting, free from grit, mixed with linseed oil.

Glass.—Glass shall be 26 ounces, "seconds" quality, unless otherwise specified.

END OF VOLUME V.

Printed by MORRISON & GIBB LIMITED, *Edinburgh*